A WINDOW OPEN ON THE WORLD

The UNESCO Courier

OCTOBER 1963 (16TH YEAR) - PRICE 1/-STG. (U.K.) - 30 CENTS (CANADA) - 0.70 F (FRANCE)

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PROBING THE INTERIOR OF THE EARTH

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SKOPLJE, JULY 26, 1963. On this day in the early morning a violent earthquake rocked the sleeping Yugoslav city of Skoplje and in a matter of seconds felled 85% of its buildings. Over 1,000 people died in the ruins. To protect people and property from similar disasters, engineers and scientists in many lands are working to design buildings that will resist major earth tremors. See page 31.

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COVER PHOTO

Fiery outburst from Mount Stromboli (between Sicily and the Italian mainland) outlines the figure of a volcanist standing near the crater's edge. Volcanists like Haroun Tazieff, who took this photo, follow a dangerous yet fascinating calling. Their research into volcanic activity may one day make it possible to forecast both the violence and duration of dangerous eruptions and also to harness the immense potential forces of geothermal power. (See article page 20).

© Haroun Tazieff

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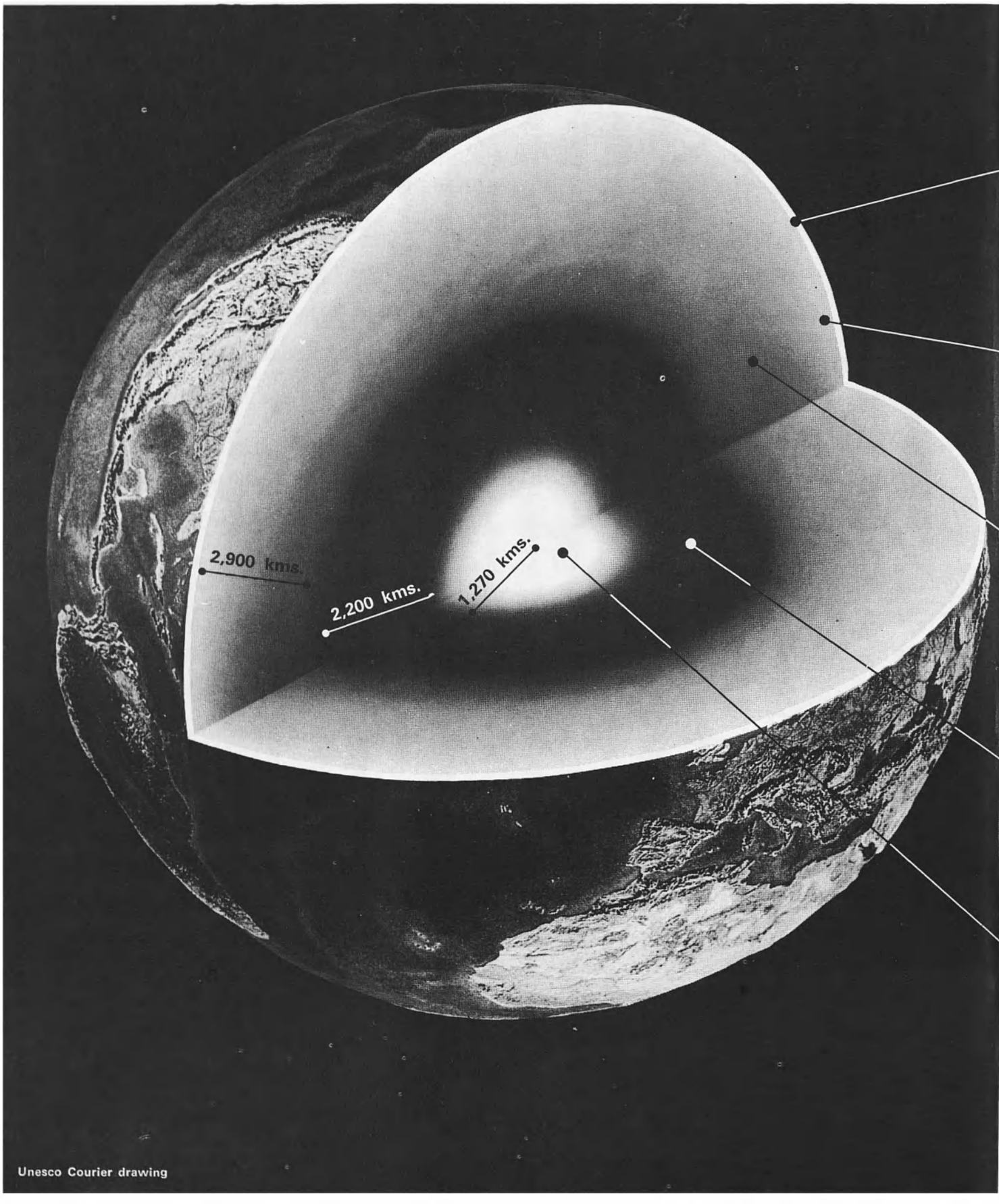
ARE THE CONTIN



Unesco Courier drawing

ENTS DRIFTING ?

by J. Tuzo Wilson

WAS the Pacific Ocean formed by the separation of the Moon from the Earth? Was there a flood or is there a lost land of Atlantis beneath the sea? Have continents moved about and was the Atlantic Ocean formed by their separation? Can the earth be shaken by any cataclysms greater than we know?

These are sensible questions which many people have asked, and which they will continue to ask until they get a unanimous and clear answer. Unfortunately that is not yet possible. We do not know all about the earth. Its deep interior cannot be penetrated and can only be explored by indirect means. Good records are not old. From our fragmentary knowledge different men find different aspects to emphasize and so reach different conclusions (1).

Since the time of the ancient Greek observations in Egypt, scientists have surveyed the shape of the earth and have agreed that it is nearly round, but other scientists who have considered its history have not been able to make such precise observations and they are not agreed upon an interpretation. Like artists, looking at the same things, they see different pictures. One, like Vermeer, sees a still and photographic image of the earth. Another, like a Van Gogh, sees a swirling, active planet. Yet another, like a Picasso, thinks that the continents have been displaced; that Greenland was once the head of Europe; that Africa and South America are twins which have been torn apart to form the South Atlantic Ocean.

The different ideas held about the earth can best be emphasized by a historical treatment to show how fresh evidence has changed men's views.

From the early maps of travellers and navigators, from observations upon soils and rocks by farmers and builders and from studies of terrain by soldiers the sciences of astronomy, geology, and geography have gradually emerged.

Today the shape of the globe and the topography of many countries and the age and variety of rocks all over the continents and islands are known. There remain gaps to fill, but by far the largest concern the floors of the oceans and the whole interior of the earth. Indeed virtually nothing was known about these major parts of the earth until this century, when complicated physical instruments began to be developed, which could examine hidden places by indirect means, as an X-ray camera explores the vital organs of a human being. This indirect study of the earth is the new science of geophysics.

CONT'D ON NEXT PAGE

(1) See article by Prof. Beloussov, page 12.

CRUST. The crust of the earth, sometimes called the sial, varies considerably in thickness. At the ocean bottom it can be as little as 5 kms. whereas on the continents its depth can vary between 30 and 70 kms. Projects to drill through the crust to obtain samples of the mantle below are now under way.

MOHO. (Mohorovicic discontinuity) the boundary zone between the earth's crust and its mantle.

MANTLE. Also known as the sima, it stretches from the earth's crust to the outer core. Believed to be solid but slightly plastic (and white hot) and formed of different and denser rocks than the crust. Mantle's density increases with depth.

OUTER CORE. Thought to be a mass of white hot liquid iron. Its liquid form is suggested by the fact that transverse earthquake waves are unable to travel through it.

INNER CORE. It has been suggested that within liquid outer core there may be a solid central inner core.

The earth—a soft-boiled egg

One of the earliest things discovered about the earth's interior was that it must be very hot. This was a simple deduction by miners who found that the rocks got approximately one degree hotter for every 50 metres they dug down into the earth. Thus below a depth of a few tens of kilometres, the whole interior is believed to be white hot and only the pressure of its own weight keeps much of the earth from melting. Miners also saw that the strata in mountains had been crumpled and when Kelvin and Helmholtz pointed out that the earth must be radiating its heat and cooling, it seemed obvious to all that the earth must be contracting. This was held to be the force which crumpled strata and uplifted mountains.

This view is the great classical contraction theory of the earth. It is like a photograph. No motion of continents has blurred the picture. The image of the earth's history is fixed and sharp. This view is still held by many, but a great uncertainty was introduced by the discovery of radioactivity in 1896 by the French scientist Becquerel. Radioactive elements produce heat. No one can measure the small but significant quantities of uranium and thorium in the earth, hence no one can tell whether the earth is cooling or heating and whether the earth is contracting. This now seems doubtful.

It took some time after the discovery of radioactivity for all the implications to be assessed, but gradually some men including A. Holmes of Great Britain and D.T. Griggs of the United States came to believe that the earth was producing more heat than it could lose by radiation. They suggested that not only was the earth not contracting, but that the white-hot mantle probably had convection-currents in it like those which rise and sink in a saucepan heated on a stove.

F.A. Vening Meinesz of Holland added fresh evidence from studies of gravity to support the idea that mountains might be formed by the movement of such currents. This picture of currents in the earth is like a painting by his compatriot Van Gogh, for according to it the earth should give the appearance of fluidity and flow.

This theory of convection currents has been particularly favoured by physicists many of whom find it theoretically satisfying, but since physicists do not in general know much geology their articles have generally dealt with idealized cases and until very recently this theory has not been fitted to the earth's existing pattern of mountains and rocks.

ANOTHER theory advanced independently as an alternative to the contraction hypothesis was that of continental drift. To understand this it is essential to record another great advance made in 1909 by the Yugoslav seismologist A. Mohorovicic. He showed that some earthquake waves are reflected within the earth from the base of a thin outer crust. Other scientists soon found a second reflecting horizon and divided the earth into an interior core surrounded by two outer layers.

We thus know that a section through the earth has a similar arrangement to the interior of an egg that has been boiled for about three minutes. The egg has a thin and brittle shell to which the crust of the earth corresponds. The white of the boiled egg, which is also solid, and somewhat plastic, may be compared to the mantle of the earth. The mantle is also solid (and white hot). Just as the white of the egg is formed of different material than the shell, so is the mantle of the earth formed of different and denser rocks than the crust.

At the centre of the earth is a liquid core, probably of white-hot iron, which can be compared with the liquid yolk of the boiled egg.

To a Danish woman scientist, the distinguished seismologist, Dr. E. Lehmann, belongs the credit for a further refinement, the suggestion that within the liquid core, in the very middle of the earth there may be a small solid centre.

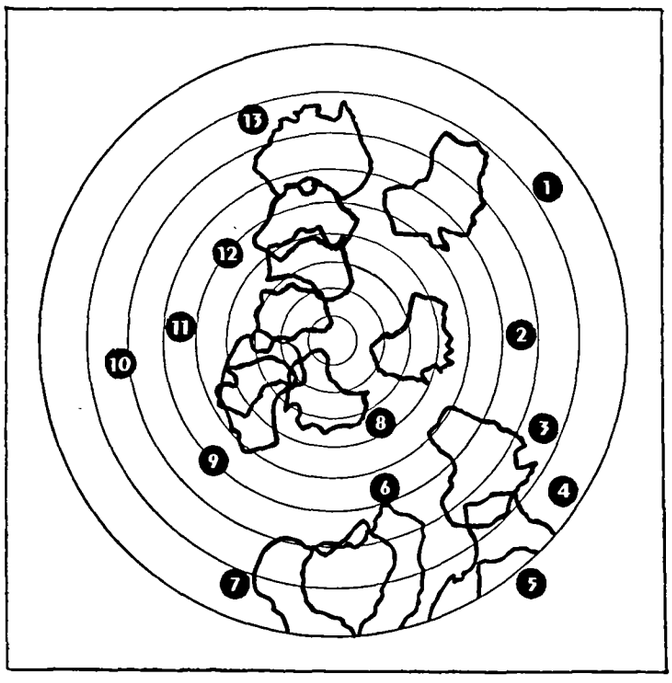
Since Mohorovicic's discovery, hundreds of determinations especially made by the United States over the oceans and by the U.S.S.R. on land have shown that under the oceans the crust of the earth is about 5 kilometres thick and is either made of basalt lava or the altered and hydrated top of the mantle. Under the continents, on the other hand, the crust is from 30 kilometres thick under the plains to as much as 70 kilometres under mountains, and it is made of granitic rocks overlain by sedimentary strata.

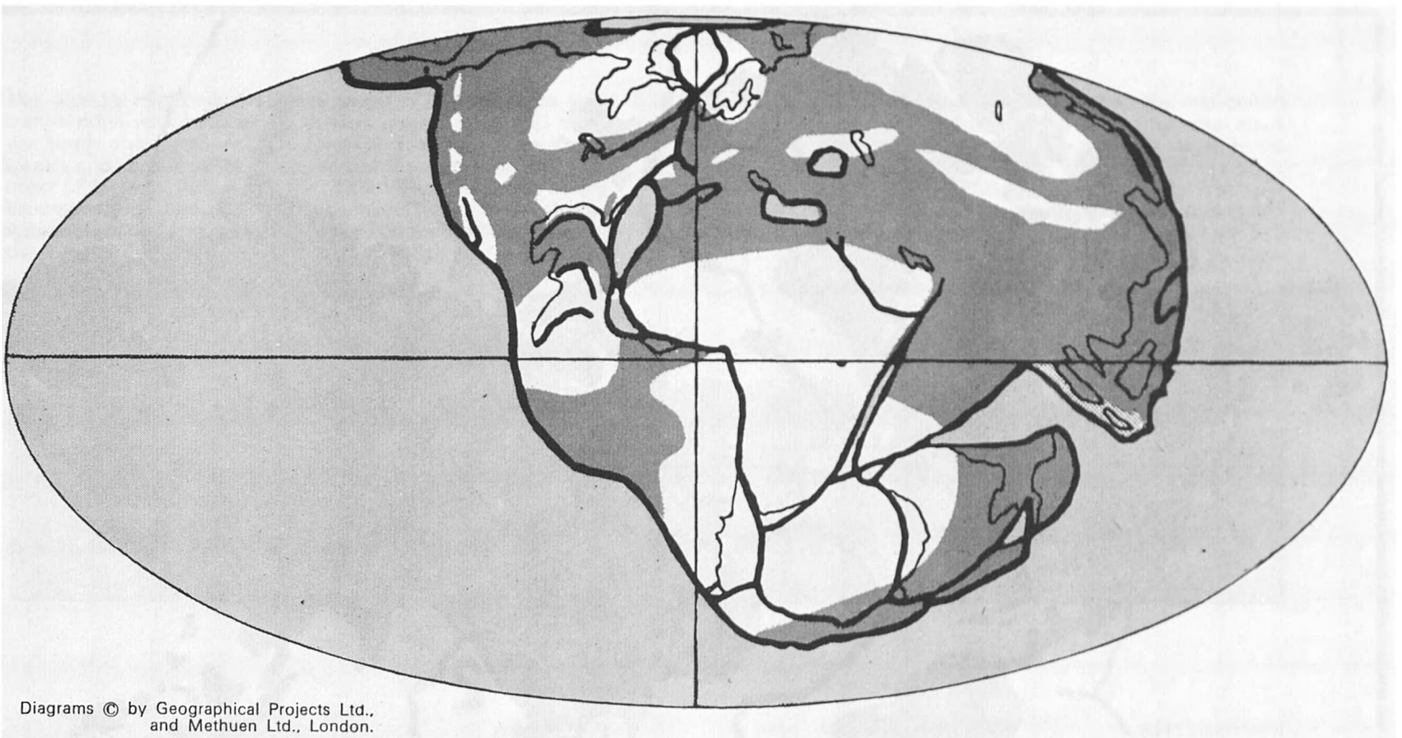
Scientists are so sure of this that the Mohole project has been started in an attempt to drill holes through the crust where it is thinnest so as to obtain samples of the material of the mantle below. This work must be done at sea, where the crust is thin (see page 18). The name Mohole is of course a tribute to Mohorovicic who first

CONT'D ON PAGE 8

WANDERING AUSTRALIA. Recent studies of magnetism in rocks have opened up new fields for discussion of the idea that continents may have moved great distances during the earth's history. Professor S.K. Runcorn, a specialist in palaeomagnetism, has seen evidence of continental drift in the changes found in the direction of the magnetism of the earth's rocks. An example of this is seen in the various positions of Australia relative to the pole, plotted by Prof. Runcorn. According to this diagram, beginning in the Pre-Cambrian period (over 600 million years ago), the continent set off from position (1) on a journey through geological time. It sometimes approached and sometimes receded from the pole at various times before finally reaching its present-day position (13).

From " Continental Drift " edited by S.K. Runcorn © 1962 by Academic Press, Inc.





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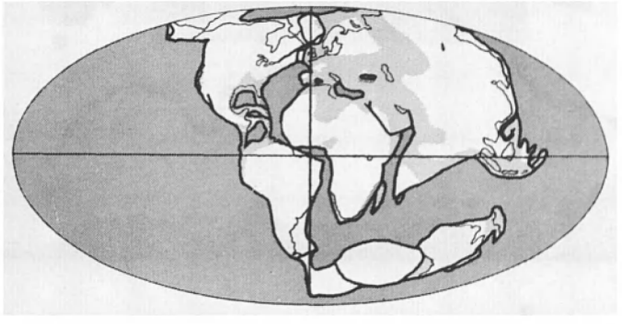
WEGENER'S SUPERCONTINENT



ALFRED WEGENER

From " Continental Drift "
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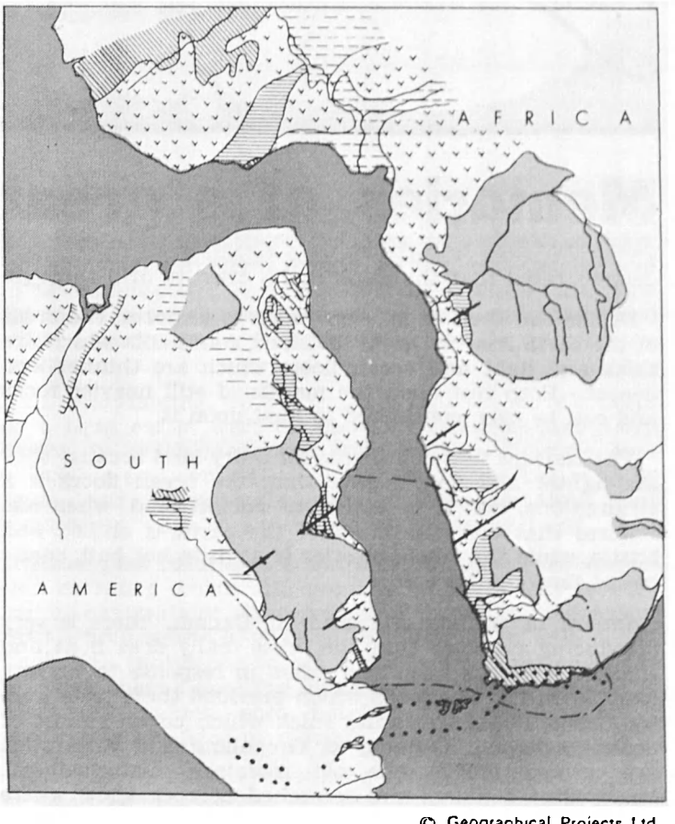
When in 1912 the German meteorologist Alfred Wegener formulated his theory of continental drift the notion was pooh-poohed by most scientists. Today, however, a growing number are less sure the principle was wrong. Wegener, like many persons before him (including Bacon) was struck by the fact that the hump of South America fitted the coastline of Africa, and pointed to an amazing number of affinities of fossils, rocks and structures on opposite sides of the Atlantic as evidence of his theory. He believed that all the continents were once joined together in one supercontinent which later fragmented until they formed our present land masses. Maps, above, first appeared in Wegener's "The Origin of Continents and Oceans". (Present coastlines are shown and lighter shading indicates former shallow seas.) In 1937 one of Wegener's followers, the South African geologist A. L. Du Toit suggested that there had been two primordial continents, a northern Laurasia (Europe, Asia and North America) and a southern Gondwanaland (South America, Africa, Antarctica, plus India and Australia) separated by a seaway (Tethys). He made the detailed jigsaw-puzzle analysis of the ancient rock structures of the African and South American shorelines, shown in the map on right.



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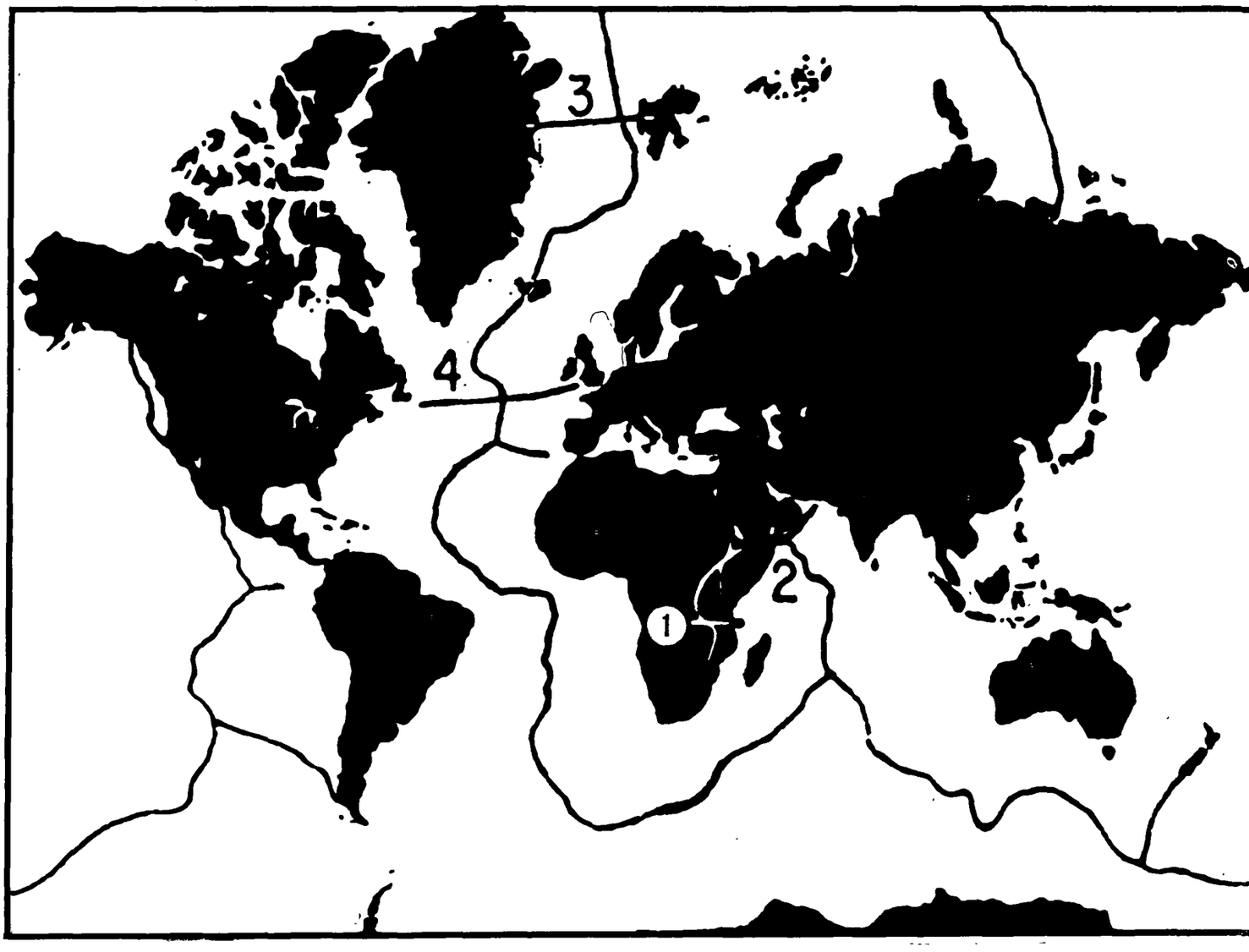
Cretaceous-Eocene
Gondwana
Pre-Silurian
Old Granite

Silurian-Carboniferous
Post-Triassic uplifts
Cape foldings
Limit of Mesosaurus
Post-Nama foldings



Memories of a great flood

demonstrated that the earth had a crust to drill through.

Unlike the shell of an egg, which is uniform, the crust of the earth has two great divisions, continents which are thick and light and ocean floors which are thinner and denser. Both rest upon the mantle of still heavier rocks and can be even considered to float upon it.

The concept that continents form dry land because they are lighter and float higher than the ocean floors is a strange one, but it is easier to comprehend when one realizes that only the crust of the earth is chilled and brittle, while the whole interior is a white hot ball, capable of slow, plastic creep.

Indeed in Scandinavia and in Canada there is very convincing evidence that the crust really does float and that its level has risen and fallen in response to varying loads upon it. The loads which provided these tests were ice-sheets, about two miles thick which covered most of Scandinavia and Canada, as Greenland and Antarctica are covered today. The old moraines, disturbed soil, transported boulders and scratched bedrock show where these ice sheets lay until they melted rather quickly due to a sudden warming of the climate about 10,000 years ago.

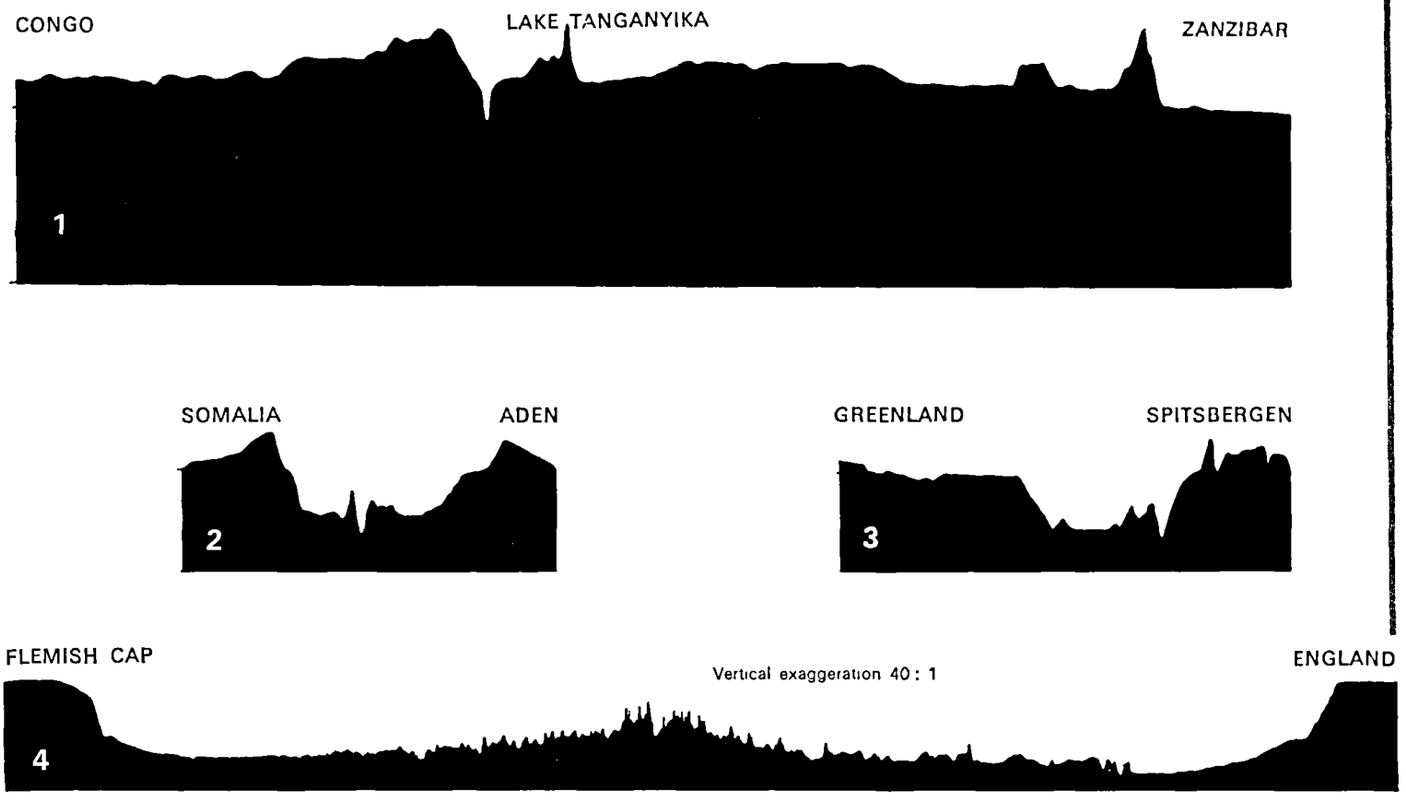
This removal of the loads which had been depressing the land allowed it to rise or float very slowly upwards and many beaches, formed at sea level, but now raised as much as several hundreds of metres above it record the steady elevation of the land where it had formerly been depressed. The maximum rate of rise of the land is about one centimetre a year in northern Finland.

Incidentally the melting of such enormous volumes of ice affected sea level all over the world. The addition of so much melt-water raised sea level by about 50 metres in places which had not been glaciated and must have flooded many coastal settlements. It seems probable that memories and traditions of this great flood have been handed down to us. This inundation is a possible source of the story of Atlantis, which the movement of continents could not possibly provide, because human history and existence are so young compared with major geological events.

When the capacity of the earth to flow and move up and down in a vertical direction had been demonstrated, one can understand the great significance of the suggestion made in 1912 by the German meteorologist, Alfred Wegener, that if the land could slowly move up and down that it might also be able to move sideways at a similar rate of a centimetre or a few centimetres a year.

He suggested that, if this happened, the parallelism of the two sides of the Atlantic Ocean could be explained. For, at that rate, Europe and North America could have moved apart in a few hundred million years. The earth is so old that there is time, even at such a slow rate for oceans to have been opened and closed, perhaps not just once, but several times.

The world's mightiest mountain range is a continuous submarine ridge with a rift along its top running (map left) down the North and South Atlantic Oceans, then across the Indian Ocean and, south of Australia, across the Pacific to the west coast of Mexico. It is hundreds of kilometres wide and several kilometres high and its rocks are unusually hot and volcanic. A branch of the Indian Ocean ridge has invaded Africa along the Great Rift Valley which cleaves the high plateaux of East Africa. Some scientists have concluded that the mid-ocean ridges mark the places where present continents split apart and see the Rift Valley in East Africa as an early stage in the development of a new ocean and the beginning of the fragmentation of Africa. Profiles below show the close similarity of the rifted ridge in Africa and three ocean ridges including (4) the Atlantic Ridge. Locations of profiles are shown on left.
From " Continental Drift " edited by S K. Runcorn © Academic Press Inc.



Some scientists immediately opposed his ideas and many do so still. Others supported it from the beginning, in particular geologists in India, Africa and Australia, who had already noticed many striking similarities between the fossils and strata of their continents. But they could only study the land surface and for many years the proponents of drift could neither explain what caused continents to move, nor could they see the ocean floor where the evidence of rifting and the passage of continents should lie. This was a great weakness.

This idea of moving continents about did not appeal to most believers in a fixed and contracting earth. They were like admirers of Vermeer who have been shown their first Picasso. They did not like it and they said that continental drift was non-representational, which is a much more derogatory epithet when applied in science than it is in art.

Yet another hypothesis is that the continents have been growing. It was first advanced by geologists who noticed that mountain ranges are often peripheral to continents. They suggested that successive ranges had been added without any motion of the continents. The work of Italian, Japanese and German scientists upon volcanoes and more recently investigations in Hawaii have shown that lava probably rises from depths of the order of 100 kilometres and that it may accumulate as additions to the crust.

Hess at Princeton and Dietz and Menard in California have discussed how these additions might be converted to continental foundations. Modern geochemistry, which was founded by such Russian scientists as Vernadsky, Fersman and Vinogadov and by Goldschmidt of Norway, has been used to support the idea of growth as have isotopic studies in Great Britain, Switzerland, Canada and in Massachusetts. These include the discovery that the shields of old rocks in the heart of continents are zoned with a tendency for the older rocks to lie towards the centres.

In recapitulation we can thus see that the early concept of a rigid earth, with permanent continents and ocean basins, in which mountains were built as a consequence of cooling and contraction, while still considered valid by some has increasingly been replaced by three new hypotheses, each of which is incomplete by itself.

These new theories are the physical theory of convection currents, which still requires to be related to geological observations ; the geological theory of continental drift which needs a physical explanation of why continents are considered to move and what force can exist to move them ; and the geochemical idea of growth of continents, which does nothing to explain whether continents are fixed or moving.

The rest of this article will be devoted to a summary of some of the discoveries of the last few years. These provide a suggestion that it may be possible to integrate all three of the more recent theories into a more satisfactory replacement for the now generally out-moded contractive theory of the earth's behaviour.

One of the great new discoveries has been largely due to the French scientists Chevallier and Thellier, although

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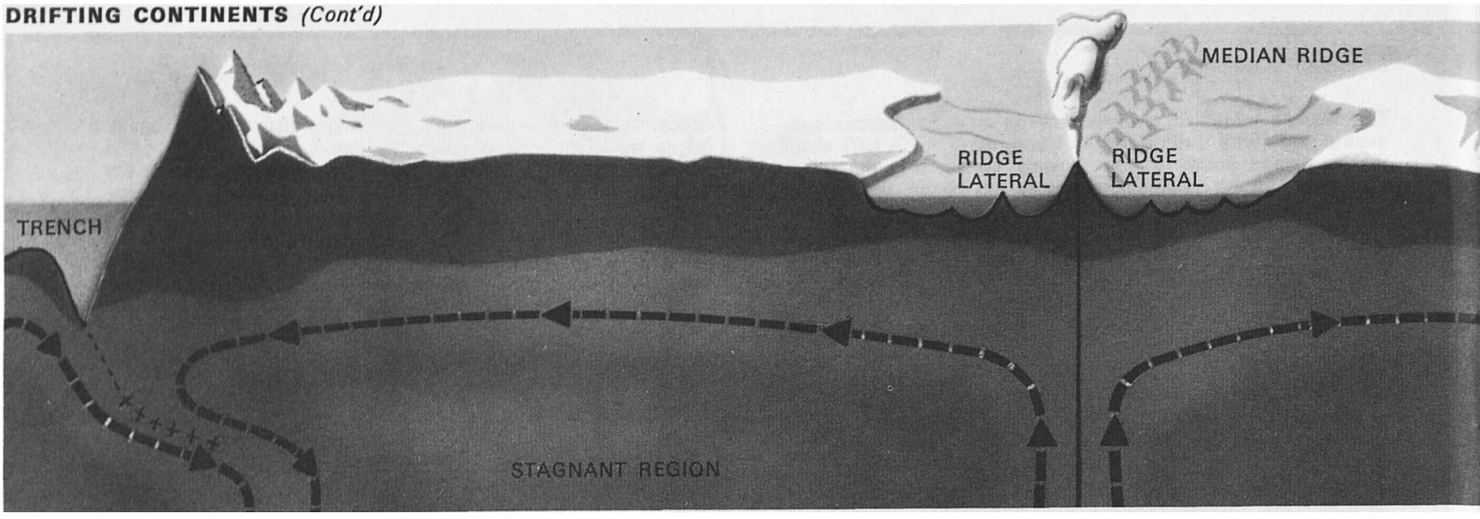

From "' Scientific American ", April 1963

20,000 leagues of mountains under the sea

it has been followed up in Britain and Australia. This is that when rocks are formed, whether by sedimentation or by the cooling of lavas, they are likely to have locked into them a record of the prevailing direction of magnetization.

This depends upon the latitude in which they lay. In older rocks this is found in general to be different from their present latitude. The progressive nature of the change observed in rocks of several ages collected from the same region suggests that several continents have been systematically moving. In particular Africa, India, Australia and South America seem to have been moving northward. Here is evidence favouring continental drift.

Modern exploration of the sea-floors has provided two other important pieces of evidence to help to solve the riddle. On the floor of the Pacific Ocean several great fractures represented by cliffs up to 3 kilometres high and as much as 3,000 kilometres long have been discovered, Comparisons of the two sides of these scarps have suggested horizontal displacements along them of as much as 1,400 kilometres. Such motions are the largest known and begin to approach those required for continental drift.

In 1956 M. Ewing and B. C. Heezen of Columbia University, New York, made a most remarkable discovery. They suggested that a number of great ridges known to exist on the floors of the oceans were continuous and formed a single mountain chain right down the middle of the North and South Atlantic Oceans, thence south of Africa across the Indian Ocean and south of Australia across the Pacific Ocean to the west coast of Mexico.

Upon this great mid-ocean ridge lie many active or recently active volcanic islands, including Iceland, the Azores, Ascension, Tristan de Cunha, Kerguelen, and Easter Island. This submarine ridge is the greatest mountain system in the world, for it extends for the best part of 20,000 leagues under the sea; it is everywhere hundreds of kilometres wide; and it is several kilometres high.

The properties of this ridge are even more remarkable. Its rocks are unusually hot and volcanic. In the Atlantic and Indian Oceans it lies very precisely in the middle of the Oceans, half way between adjacent continents. It seems to be in the process of being torn apart, in contrast to the better-known young mountains on land which have been compressed.

There are thus two great mountain systems on earth, complementary to one another. The mid-ocean system has just been described. The continental system which was first recognized by E. Suess, an Austrian, consists of two belts, one around the borders of the Pacific Ocean and the other across Eurasia. The first consists of the Andes, and Cordilleran mountains and the island areas of the Aleutians and East Asia through Kamtchatka, Japan, the Philippines, Indonesia, New Guinea and small islands to New Zealand. The other belt consists of the Alpine and Himalayan mountains extending from Spain all the way across the Mediterranean and Southern Asia to join the first belt in Indonesia.

When we consider the concept of convection currents in the light of these discoveries, it seems possible to believe that the upward currents might be rising beneath the mid-ocean ridges and sinking beneath the better known belts of continental mountains and island areas.

According to this view the heat, the volcanoes and the tension which marks the mid-ocean system derive from hot currents that rise to feed volcanoes and separate to tear the brittle crust apart while the characteristics of the continental mountains are a result of the flowing together of the same currents to produce compression. Their descent sucks down the great deep trenches of the ocean all of which lie close to chains of islands, off Kamchatka, Japan, the Philippines, the West Indies and elsewhere. The crust and upper mantle, are cold and brittle and earthquakes occur when it is broken due to flow beneath.

An important contribution to this theory is Hess's suggestion that whereas the continents are true rafts of lighter material, the oceanic crust is only altered mantle top which on being dragged down reverts to unaltered mantle again.

This concept provides a geographical and a geological setting that was lacking in earlier discussions of convection. There is even some evidence that the direction of flow is recorded in ridges or stream lines on the ocean floors.

Unfortunately, although we may believe that we can map the direction of flow, we cannot yet measure it directly. It is thought to be only about three centimetres

One of the more challenging and controversial ideas recently advanced is that continents have moved to their present positions under the impulsion of convection currents welling up from deep in the earth's mantle. The same process has also been said to have created the world's mighty mid-ocean submarine ridge and has formed mountain ranges and earthquake belts. Drawing, left, illustrates this theory. On right currents move up in area of mid-ocean ridge, feeding presently-active volcanoes (Tristan da Cunha, Iceland, Azores, etc.). Inactive volcanic cones which have been moved sideways by flow of convection currents form lateral ridges. Continent, on left, has been pushed along to point where convection current sinks towards earth's centre. Since continents are lighter than the mantle material of the ocean floor, they are not sucked down into the deep oceanic trench created by the current, but pile up to form mountains. Earthquake zone is created (crosses) when cold and brittle crust and upper mantle is broken because of flow movements of convection current beneath.

a year and this small change cannot be measured across the width of an ocean.

If we accept this concept it also can provide the mechanism which was missing in early statements about continental drift: one must suppose that the currents have carried the continents like rafts away from the mid-ocean ridges—equally on either side—until they have become stranded at the edge of down currents.

The Americas and East Asia, are pushing against the downflow around the rim of the Pacific Ocean, while India, Arabia and Africa are thrust against Eurasia over another downward flow. The current has been carrying these continents and also Australia northwards, which agrees with the observations on remanent magnetism.

The periodicity of mountain-building can also be understood. This periodicity is shown by the fact that in Europe the Alpine chains have replaced the formerly active mountain chains of Scandinavia, of the Urals and of Scotland while in North America the Rockies have taken the place of the once great and active Appalachian Mountains.

If drift has been going on it has not occurred just once but by changing patterns of convection currents within the white-hot, solid but slightly plastic mantle, like currents boiling in a pan, but on a infinitely greater and slower scale.

Each different pattern has produced a different mountain chain, first one added on one side of a continent, then one on another. Elsewhere, when a new rising current has started, continents have by the same process been torn apart, as is happening, or so it appears, in the Red Sea, and in the rift valleys of Ethiopia, Kenya, Rwanda, Burundi, Congo and Tanganyika today.

We have spoken of the growth of continents. That they do grow is a view more widely held than that they move. From what do they grow? The first rock produced by partial melting in the earth is basalt which flows so abundantly to the surface in Iceland, in Hawaii and has done so in the past in the Deccan of India and in the Parana basin and Patagonia of South America.

The basalt, erupted on the sea floor, is eventually carried by convection currents into the ocean deeps where it is inexorably dragged down by the same currents to be melted and to rise again.

Such are the complications of silicate chemistry that each melting leads to the separation and eruption of rocks more siliceous and also less dense than their parents. Basalt is lighter and more siliceous than the mantle ; the new volcanoes such as those of the Andes, Italy, Japan, Indonesia and of the continental margins are in general yet more siliceous than basalt.

These rocks are eroded again, some to be carried back to the ocean trenches where they can again be dragged down and remelted, others are laid down as stratified sediments, others again are recrystallized into continental basements. As the complex process continued soils developed and the home of man was prepared for him.

The age of the earth is perhaps four or five thousand million years. The record of the first third of that history has been lost, but the rocks preserve the rest and now that we can indirectly explore the earth's interior and its ocean floors we are approaching the time when we will have a satisfactory and agreed theory with which to unravel that history. In the meantime it is only fair to say that the scientists are still arguing one with another as they struggle to solve these problems.

Here the progress being made in those attempts has been reviewed. There is not yet general agreement, but an agreed solution seems to be in sight. Perhaps there is enough agreement to offer answers to the initial questions which we raised. Most workers agree that although the Earth and the Moon may have been formed together, that so many changes have occurred on earth and that the properties of the moon differ so much from those of the earth's surface, it is most improbable that the Pacific Ocean basin has anything to do with the moon.

If Atlantis was lost beneath the sea it probably is a memory of a great flood which occurred due to the melting of North America and Scandinavia ice-sheets 10,000 years ago. In any case it has nothing to do with the major events of geological history which occurred long before mankind had appeared on earth.

It is quite possible, and becoming more probable all the time as new evidence pours in, that continents have moved apart and that the Atlantic Ocean is a result of the separation of Europe from North America, and of Africa for South America. Not all scientists agree to this yet, and once one accepts that the continents can move there are an infinite number of ways in which they might have done so.

The rapid rate of exploration of the ocean floors and of geophysical discovery should soon lead to a firm decision. This is badly needed, for until it is settled whether continents have moved, and if so by what paths, no complete answers are possible to the major problems of geology, of geophysics, of past climates and of evolution itself.

We are sure that in all the vast record of the rocks, there is no evidence of immense earth-shaking convulsions. The earthquakes, typhoons and volcanic outbursts that man has experienced are terrible enough, but their effects are local. We believe that the earth has developed in gradual majesty by the slow operation of the same processes that we see in action about us today. The earth is stable and our home is a safe one.

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World scientists join in a great venture

THE UPP

GEYSER POWER. Jets of steam and superheated water which shoot out of the ground in countries like Iceland, New Zealand, Japan, the U.S.S.R. and the U.S.A. are the tell-tale signs of a vast subterranean thermal power of which comparatively little use has so far been made. Proven resources in the U.S.S.R. alone of this new "mineral" could replace a calculated 100 million tons of coal annually. In Kamchatka the first Soviet power station working on thermal waters is now being built and near Omsk water for household purposes is already being tapped from one of the world's largest reservoirs of hot water extending over an area of three million square kilometres in West Siberia. Below, steam from geysers drifts across the empty landscape 14,000 feet up in the Atacama Desert area of the Chilean Andes.

Mike Andrews © Holmes-Camera Press

ER MANTLE PROJECT

by Vladimir V. Beloussov

In many respects we know more about distant space than we do about what is going on under our feet. The deepest shaft so far sunk anywhere in the world is little more than seven kilometres in length —a mere pin-prick compared to the earth's radius which is about 6,370 kilometres.

Even the vast research programme of the recent International Geophysical Year (1), during which thousands of scientists from all countries joined forces in studies designed to reveal the secrets of our planet, was mainly concerned with the study of physical phenomena taking place above the solid crust of the earth—in the oceans, in the lower layers of the atmosphere, in the upper atmosphere and in circum-terrestial space.

The International Geophysical Year marked an epoch in the history of the study of our planet. A completely new picture of the life of the oceans was obtained: currents were found at great depths, thus exploding the old theory that waters lying immediately above the ocean bed are stagnant; new mountains, mountain ranges and depressions at the bottom of the ocean were mapped; huge deposits of minerals were found scattered on the sea bed in petrified form.

The study of glaciers enabled scientists to estimate the volume of ice in the world and to show that the quantity is diminishing. Antarctica was "rediscovered," for more was learned about it during the I.G.Y. than in all the time that has elapsed since men first reached this icy continent.

The I.G.Y. produced other results. It gave rise to new forms of co-operation between scientists and provided an inspiring example of the way in which international collaboration can be developed in this domain. But its results came almost entirely from observations made on land, in the waters and in the air. The I.G.Y. paid little attention to the interior of the planet.

It is true that some information about great depths, even to the very centre of the earth, has been obtained by geophysical means. But this is indirect information. The data obtained tell us something of the physical properties of the material of which the earth is made, but reveal nothing of its chemical composition or of its crystal and mineralogical structure.

The most widely used geophysical method is seismography. Elastic seismic waves from earthquakes or man-made explosions are studied during their passage through the inner layers of the earth, and from their behaviour scientists are able to determine some of the physical properties of the matter they penetrate. Our conception of the internal structure of the earth has been built up mainly from the valuable information so acquired.

If to this we add our ideas about the distribution of pressure and temperature inside the earth, we build up quite a good picture of the material contained in the inner parts of our globe. At best, however, these are only assumptions and several different yet equally plausible deductions may be made from the same data. Even today, scientists are not in agreement about the composition of those layers of the earth's crust that cannot

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(1) *See The Unesco Courier, Sept.* 1957 *and Jan.* 1962.

The unknown beneath us

be reached by drilling to say nothing of the deeper parts of the planet.

There is still considerable controversy regarding the processes going on inside the earth, processes that cause the slow or rapid movements of the crust and the rise of molten magma towards the surface; this magma either remains below the surface as a solid body or breaks out through the mouths of volcanic craters.

It may be asked whether it really is important for us to know what the earth is made of at great depths and what processes are going on inside it? There can only be one answer to this question—Yes! The theoretical problems concerning the composition and structure of our planet and the processes taking place inside it are of the greatest importance. We live on earth, and no matter how far away future cosmonauts may venture, they will eventually return to this planet which will continue to be man's real home. It would be strange if we had no urge to know what our own house is made of or were satisfied to make only chance guesses at what is hidden in its distant storehouses and even in those quite close to us.

The problem also has a practical significance that becomes all the greater as time goes on.

Modern technology, all modern civilization, in fact, depends on mineral resources, because technology and civilization itself are based on the use of metals dug out of the earth in the form of ores. The raw materials for our power supplies—coal, oil, gas and atomic raw materials—are also extracted from the earth. Lastly, building materials, too, come from the earth.

As technology develops man requires more and more mineral wealth, but the minerals are becoming harder to find. Man began to use stone to fashion his first instruments—axes, hammers, scrapers, knives—by picking up what was lying on the surface and adapting it to his needs by chipping, shaping and grinding.

The first ores for smelting were obtained from places on or near the surface. As time went by surface supplies became exhausted and man had to delve deeper and deeper into the earth to find the minerals he needed. Thus mines have reached depths of over three kilometres and wells have been sunk to a depth of over seven kilometres.

As the most accessible resources run out, the prospecting of mineral deposits at greater depths becomes increasingly difficult. When geologists prospected for deposits lying at depths of a few dozen or a few hundred metres, they often found clues to their presence on the surface.

A spring containing iron pyrites, for example, might indicate a deposit of ore some distance down. But when deposits lie at a depth of several kilometres it is no use counting on such tell-tale signs. These "blind" deposits are completely hidden inside the earth and give no indications of their existence on the surface. What is the geologist to do under these circumstances?

It is here that the theory of scientific forecasting comes into the picture. It should be possible to forecast which minerals we may expect to find in the depths of the earth and where they lie. The theory must be based on a correct conception of the conditions under which various minerals are formed. Many minerals, metal ores, for example, result from processes taking place in molten magma. They are crystallized either directly out of the magma, or out of the hot aqueous solutions or vapours that rise from the magma as it solidifies inside the earth.

Movements of the earth's crust have a tremendous effect on the formation and accumulation of minerals. Such movements lead to the appearance of crevices in the crust, vapours and solutions rise up through these cracks and deposit metal ores on their walls in the form of minerals.

HOW TO BEND ROCKS: Originally deposited in horizontal layers, these rocks in the Caucasus Mountains have been squeezed into their present weird shapes by the colossal forces of the earth's tectonic movements (the rising and sinking of its crust). In laboratory experiments designed to show how these rock folds came into being, scientists have reproduced processes that took nature millions of years to complete.

Official Soviet photo

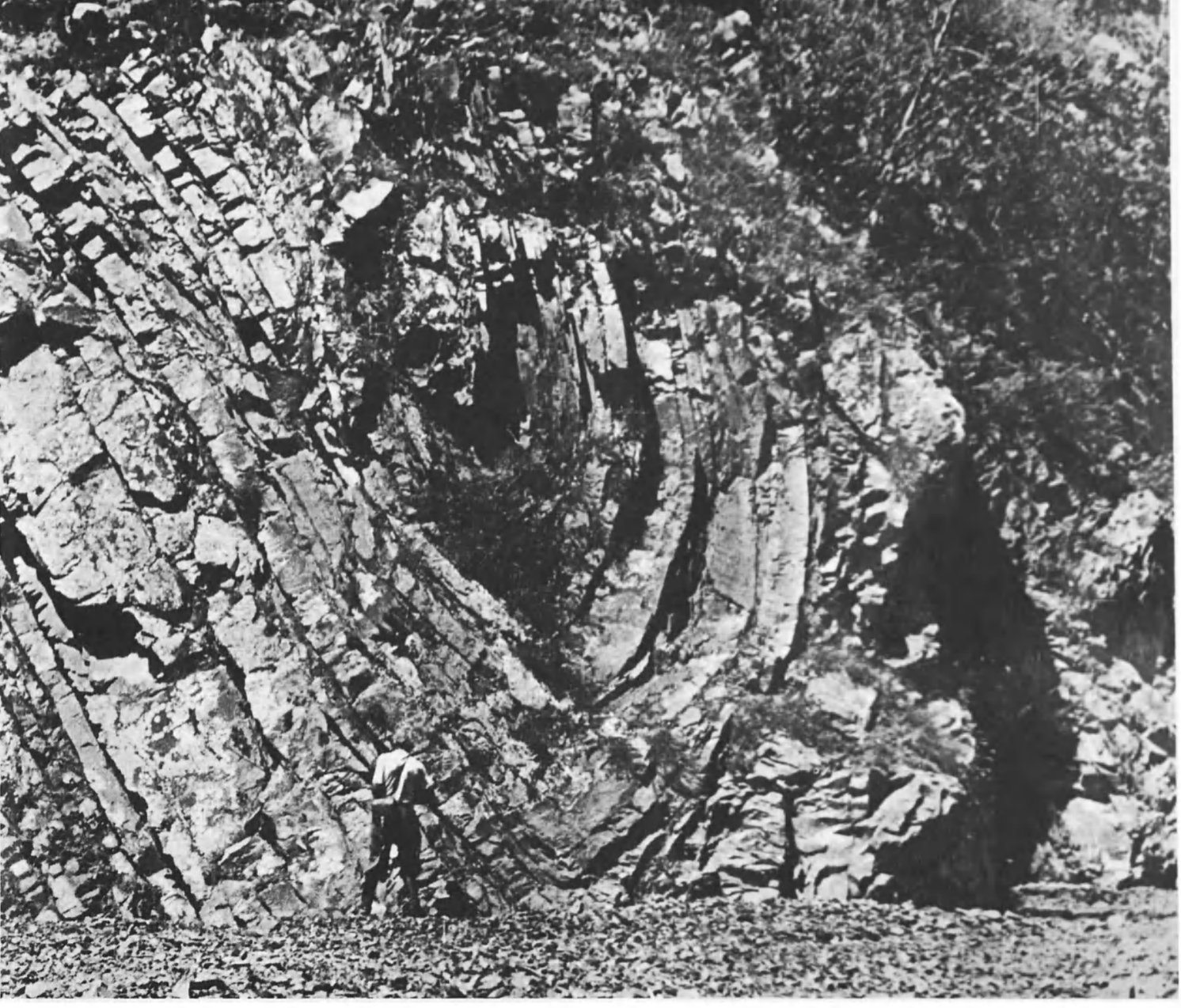
The movement of the crust also leads to the bending of its layers and the formation of domes and undulating folds. Dome-shaped folds, or bulges, offer favourable places for the accumulation of such light minerals as oil and combustible gas.

From this it follows that to evolve a theory capable of giving an accurate forecast of which minerals we may hope to find and where they are to be sought, we must understand the causes of the formation and movements of the molten magma, the causes of the movements of the earth's crust and also the natural laws governing these movements.

The movements of the crust are called tectonic movements: they take the form of the slow rising and sinking of the earth's surface, the crushing of the strata into folds, the formation of crevasses, and, lastly, earthquakes. Incidentally, an explanation of the causes of tectonic movements and the laws governing them, is also necessary for the elaboration of methods forecasting the probable times and sites of future earthquakes.

The causes of magmatic phenomena and tectonic movements are buried deep down inside the earth; a thorough study of those depths must therefore be made for practical as well as theoretical reasons. We now know that the main causes of the formation and rise of magma and of all tectonic movements are to be found below the crust, in the layer of the earth known as the mantle; the mantle stretches all the way from the crust to the earth's core, which lies at a depth of 2,900 kilometres from the surface. It is only the upper part of the mantle, to a depth of about a thousand kilometres, that is active.

This outer mantle is today believed to be the place where



magma originates and from where it rises to the surface; here, too, the movement of matter and changes in its volume begin and these processes are reflected on the surface as movements and deformations of the crust.

The need for further investigation led to the elaboration, in 1960, of an international research project; the plan has been given the name of the "Upper Mantle and its Effect on the Development of the Earth's Crust," or, more briefly, the Upper Mantle Project. The scheme has attracted the attention of scientists all over the world and many countries have announced their readiness to participate.

The general purpose of the project is to extend as far as possible our knowledge of the composition of the crust and upper mantle and of the processes taking place in them. The "heart" of the project is the combination of the methods employed by all branches of science that study the earth—geophysics, geology, geochemistry and geodesy.

At one time, geology was the only science that studied the interior of the earth, its structure and development. Owing to the limitations of its methods, geology was unable to "see" more than a few kilometres into the earth, and then only on dry land. In the present century two new branches of science, geophysics and geochemistry, have emerged; they study the deep regions of the globe that geological methods are unable to reach.

As we have seen, the data provided by these sciences are indirect, whereas geology provides direct information about the upper layers of the earth's crust. Unfortunately, geologists, geochemists and geophysicists have been, and still are, working independently of each other, but if they are to solve the problem of the nature and causes of magmatic and tectonic phenomena they must combine their efforts in joint studies.

Geology cannot carry out the task alone because information on the outer mantle, where the causes of magmatic and tectonic phenomena are to be found, can be obtained only from geophysical and geochemical data. Geophysics and geochemistry are also unable to carry out the work alone because account must be taken of the way magmatic and tectonic processes are reflected on the surface and also of their history throughout geological time. Geodesic measurements are also important for the study of contemporary movements of the earth's crust.

The general problem set for the Upper Mantle Project must be solved by comparing the surface structure and development of the earth's crust with the structure of the lower layers of the crust and the upper mantle. The surface of the earth's crust is divided into numerous areas differing in structure or in history. These are usually called tectonic areas, and the concrete task of the project is a comparative study of their structure in depth.

Examples of these areas on the continents are the folds of various ages, stable platforms, crystalline shields, and so on, and in the ocean, abyssal valleys, very deep, narrow trenches, submarine mountain ranges, etc. The continents and the oceans are themselves the biggest tectonic divisions.

Geology, mainly the branch known as geotectonics, has shown us that individual tectonic areas reflect different

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The deep roots of the earth's crust

stages in the development of the earth's crust. At some time in the past the entire crust was extremely mobile. Folds were formed, mountains took shape, and magmatic processes were very active.

Later, in a period separated from us by some 1,500 million years, stable areas, or platforms, began to make their appearance while the crust surrounding them continued in a state of turbulence. The platforms gradually increased in area and the moving strips between them grew narrower.

Then, in the last period of geological time, about twenty million years ago, the platforms came to cover the continents almost completely and a new form of activity began: mountains appeared on the platforms as secondary formations. Thus the highest mountains now in existence, such as the Tien Shan, the Pamirs, the mountains of Tibet and still others, came into being. From this we see that the stage of secondary mountain formation followed the platform stage and the latter came after the stage of the great mobility of the earth's crust.

It is important to bear in mind that the earth's crust is not developing evenly; some areas go through their development rapidly, others lag behind. For this reason tectonic areas belonging to different stages of development exist side by side and we are able to observe them simultaneously.

This is an advantage to us; it enables us to get a picture of the deep-lying structures under each tectonic area and to determine the way in which its structure changes with time. We have only to compare the structure in depth of those areas belonging to early stages with those that belong to later stages to be able to get some idea of the nature of the processes taking place at great depths.

So far we actually know very little about the structure of the earth's crust and of the upper mantle, but the little we know allows us to make some interesting assumptions.

It has long been known from seismographic data that the earth's crust has a different structure under the continents and under the oceans. It is thicker under the continents (averaging 35 kilometres and increasing under the mountain ranges to as much as 70 kilometres). Under the oceans, the crust is no more than five or six kilometres thick.

The crust under the continents consists of several strata, of which the most important are the upper, or "granite" and the lower, or "basalt" strata. The upper stratum, according to geological data, has a thickness ranging from ten to twenty kilometres and is actually composed of granite or similar rocks.

Nothing whatever is known of the composition of the so-called "basalt" stratum. It has been given that name because elastic seismic waves penetrate it at the same speed as they penetrate basalt, a volcanic rock rich in magnesium and iron.

Under the oceans, there is no granite stratum at all and the crust there consists only of a basalt stratum (not counting, of course, the seabed deposits). In this case it is extremely likely that the stratum actually consists of basalt, because the numerous volcanoes on the ocean bed and on oceanic islands erupt only basalt lava. The oceanic crust, too, is thicker under the mountains and thinner under the plains.

The earth's crust is bounded below by what is known as the Mohorovicic Discontinuity, named after the Serbian scientist who discovered it. In passing this divide the velocity of seismic waves undergoes a sharp change. Above the divide the velocity is lower; after passing the divide it is noticeably higher. The earth's mantle begins at the divide, and the first thousand kilometres of it constitute the upper mantle. We do not know what the upper mantle is made of, but there is no doubt that it is solid matter and that it is heavier than the materials which make up the earth's core. It contains a larger component of magnesium and iron than the "basalt" stratum.

Until quite recently it was believed that although the crust changes in structure and thickness from one tectonic area to another, the mantle is everywhere identical. It has now been established that this is not so. The first discovery was the difference in the structure of the upper mantle under the continents and oceans.

In both cases the mantle contains a stratum that is somewhat softer than the strata above and below it; in this stratum the velocity of seismic waves is slightly lower than in the other strata. This soft stratum is called the asthenosphere. It seems to be of great importance, since molten magma is born there and it is the site of those movements of matter and changes in its volume that affect the surface in the form of tectonic movements.

It was then discovered that this asthenosphere is thicker under the oceans than it is under the continents (300 kilometres as compared to 150 kilometres). Furthermore it is now known that the mantle also differs in structure under tectonic areas of smaller size than continents and oceans —under folds and platforms of different ages, under big plateaux and depressions, under strings of islands and submarine mountain ranges, etc. This shows that the surface structure of the earth's crust has its "roots" at the very greatest depth, at least some hundreds of kilometres, and that the development of the crust is intimately connected with that of the outer mantle.

This knowledge has compelled us to reject all the tectonic hypotheses that assume independent development of the crust and the outer mantle and the absence of any connexion between them. One of these, the hypothesis of shifting continents, was proposed by the German geophysicist, Alfred Wegener, at a time when very little information of the earth's interior was available.

We cannot today admit the possibility of parts of the continental crust moving across the surface of the mantle. We see that the causes of movements of the crust, of the rising and sinking of parts of it, are to be found in the outer mantle; if the crust moved independently of the mantle, the rising and sinking areas would move across the surface of the continents. Such areas, however, remain fixed in one place for a very long time.

The area known as the Baltic Shield, for instance, has been slowly rising for something like 600 million years. If we accept the hypothesis of the horizontal shifting of continents, we must also assume that the crust under them moves together with the mantle. In other words, we must assume that it is not a thin crust some thirty or forty kilometres thick that moves, but a tremendous mass with a thickness of a thousand kilometres, which is obviously impossible.

Another important discovery that has been made is that the earth's crust can in the course of time not only become thicker, but also thinner. It is now known that the rising areas of the crust are thicker and the sinking areas thinner. Geological history, however, tells us that many of the areas that are at present sinking, formerly rose. This must mean that the crust under them was formerly thicker.

This discovery is important because it has led scientists to the unanimous conclusion that the crust is made of lighter materials than the mantle, and that the lighter materials were gradually exuded out of the mantle in a

molten state and floated towards the surface. This melting is due to the heat generated by the disintegration of radioactive elements.

Today there is every reason to attach great importance to the melting process in the development of the earth. It may even be basic, it may be the primary cause of all magmatic and tectonic phenomena. It might seem that the process could develop only in one direction and that the crust must, as time goes on, become ever thicker.

Actually the matter is more complicated than this ; parallel to the direct process, which makes the crust thicker, there is the reverse process, the destruction or reduction of the crust that is probably due to the melting of its lower strata caused by increases in temperature in the mantle.

If the first point of view is correct we shall have to regard the basalt crust of the oceans as the older, and as having been formed when the flow of molten matter from the mantle was still going on. In this case the continental crust must be younger, since its formation required the flow of greater quantities of light molten matter from the mantle.

If this is true, more and more new continents should be rising out of the oceans and their area should be constantly increasing. If the reverse process is taking place and the crust is becoming thinner, some continents should collapse and become ocean beds. A number of facts point to this conversion of continents into oceans as a dominant tendency in the last geological period.

Research foreseen as part of the Upper Mantle Project should provide answers to these and many similar questions concerning the magmatic and tectonic life of the earth's crust.

One interesting problem is that of the folding of rocks.

OUR RESTLESS EARTH. In an average year there are about 20 major earthquakes and hundreds of thousands of minor tremors, most of them passing unnoticed. Fissure shown here was caused in a few seconds by an earthquake which struck Mongolia on December 4, 1957. Official Soviet photo

For a long time it was believed that folding is due to the contraction of the earth's surface and the reduction of the volume of the earth. Opinions on this question have now changed. The cooling and contraction of the earth are impossible, primarily because radioactive elements inside the earth are constantly producing so much heat that it is more likely that the earth is gradually becoming warmer and not cooler.

It is probable that the primary cause of the folds is the vertical movement of individual masses, separated from each other by cracks that penetrate the entire crust and enter the mantle. These masses move up and down like piano keys. The folds are formed by layers of the rising masses slowly slipping on to lower surroundings under their own weight.

In general, there is every reason to believe that vertical movement, the rising and sinking of different areas, has the greatest significance in the life of the earth's crust. These movements are going on constantly. In the past they produced countless changes in the configuration of land and sea, they made mountains and caused depressions to form. Today these movements can be observed by geodesic methods; the usual rate of movement is a few millimetres a year, rarely as much as one or two centimetres.

THE comparative study of the various tectonic areas in accordance with the Upper Mantle Project must be carried on jointly by geophysical, geochemical and geological methods, all of which must serve to complement each other. Since not all types of tectonic areas are to be found in any one country, not even in countries as big as the U.S.S.R. or the U.S.A., it is important that the work should cover, as far as possible, the entire surface of the earth.

Great hopes are being placed in ultra-deep drilling. Two projects exist. The American project is to drill through the thin crust under the ocean floor, enter the upper mantle with the drill head and establish the composition and properties of the mantle. This project has been launched by a test drilling in the Pacific Ocean off the shore of Southern California.

The Soviet project is to drill through the continental crust for the purpose of studying the structure of the granite layer and, as far as possible, also the "basalt" layer of the earth's crust. It is not improbable that on some offshore island, where the crust is thinner at the junction of ocean and continent, the drills may reach the upper mantle. It is estimated that the first Soviet wells to be sunk will be from twelve to fifteen kilometres deep.

Thus these two projects, the American and the Soviet, will complement each other ; they are an excellent demonstration of the advantage to be gained from international scientific co-operation.

Geologists, geophysicists and geochemists expect a great deal from the Upper Mantle Project. A few years of specialized study will bring our knowledge of the interior of the earth up to a completely new level. We shall learn what matter lies in the depths and how it behaves, and then the period of vague guesses and weakly-grounded hypotheses and fantasies (of which the sciences studying the earth have had far too many) will give place to a new period of precise knowledge.

At the same time the practical possibility of using the wealth hidden in the bowels of the earth, both mineral and energy resources, will be greatly enhanced. It is well within the bounds of possibility that each deep well bored into the earth will itself serve as a source of underground heat energy since it must pass through temperature belts of 300° to 400° C.

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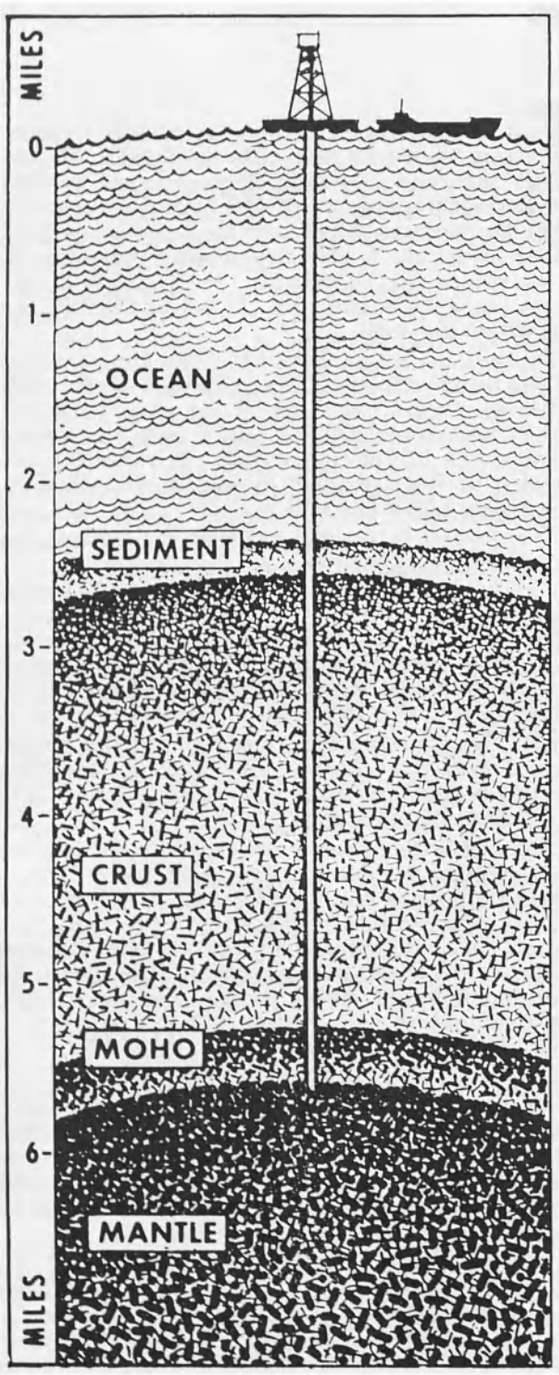
PROJECT MOHOLE



To probe and obtain samples of the earth's mantle (diagram, left), U.S. scientists plan to drill through the overlying crust under the ocean where it is relatively thin (about two and a half miles). Their objective is the crust-mantle boundary, named the Mohorovicic discontinuity after the Yugoslav scientist who discovered it (see page 4), and called "Moho" for short—hence the name "Mohole" for this project.

Test borings for the Mohole Project were made off California coast from this ship, the Cuss I, whose diamond studded drills had first to be lowered through over two miles of water before they bit into the ocean floor. To keep it in position over the drill hole the vessel had four outboard motors. Behind its derrick three miles of drill pipe were stacked.

USIS photos

Above, technicians in the test-drilling ship inspect the "guide shoe" which protects the deep-sea drill pipe and limits bending near the ocean surface. Throughout the drilling the ship's pilot had to keep the vessel in the centre of a ring of buoys. If the waves had pushed it beyond these limits the drill would have snapped. Below, scientists examine the first cores brought up from 1,000 feet below the ocean bottom.

THE HIDDEN WORLD OF VOLCANOES

by Haroun Tazieff

We still commonly hear it said that volcanic upheavals are far less violent today than they were in earlier geological periods, that they are mere pinpricks on the earth's skin, trivial by comparison with the mighty terrestial convulsions during which great ranges of twisted mountains like the Alps or Himalayas emerged from the depths of the vast oceanic abysses.

There is no doubt that during some periods in the earth's history volcanoes were more numerous and more violent than in the present brief moment of our planet's existence; but there have also been many other epochs in which volcanic disturbances were even milder than they are nowadays. It would, in fact, be a serious mistake to accept the "official" figure of between 650 and 700 volcanoes considered as currently active; this is a very restricted figure which applies solely to volcanic craters that have erupted during recorded history.

Two factors in the calculation completely falsify it. The first is the concept of recorded history itself: it amounts to two or three thousand years in the tiny areas of the old scientific civilizations of the Mediterranean and the Far East, four or five centuries in Latin America and Indonesia, two for most of the Pacific, Kamchatka and the Aleutians and only one for Central Africa—no more than the twinkling of an eye when compared to the immense duration of the geological ages!

The lives of volcanoes, however, are measured on a geological time scale. How many of the so-called extinct volcanoes throughout the world are merely dormant, sunk in sleep during which physico-chemical processes take place that will lead to new eruptions? There are perhaps hundreds, even thousands of such cases; at least as many, and probably more than those so far counted.

The second reason for this error in calculation is our ignorance about what goes on over the major part of the earth's surface in the depths of the oceans. Only now is some light being shed on its mysteries.

The odds against a submarine eruption being detected are several thousand to one. First of all the ocean is deserted to a degree forgotten by people who never travel over it and who only think of it in terms of atlases and maps. To detect the relatively rare submarine eruptions that are visible on the surface a boat or aircraft would have to be passing directly or almost directly above the eruption at the very moment (often no more than that), when it occurred. Finally, as most undersea eruptions occur at depths of several thousand yards any discharge of vapours is impossible because even 6,000 feet down, the hydrostatic pressure is greater than the critical pressure of the water.

Thus, the eruption cannot be an explosive one, and the molten lava spreads quietly over the marine depths in the same way as a sill is created between two strata within the earth's crust, but in this case between land and sea. The first gases which escape from the magma dissolve in the water on account of the high hydrostatic pressure. This also prevents the gases from making a vesicular form of lava which, reaching the surface as light pumice stones would otherwise reveal what was happening in the depths.

But a study of ancient geological deposits provides clear evidence that huge quantities of lava pour out in the ocean deeps and on the sides of the geosynclinals in which the mountains have their origin. Moreover, the great submarine range which wanders for thousands of miles in the middle of the Atlantic and Indian Oceans, the South Seas and the eastern Pacific, is most probably made up entirely of lava which has accumulated to form a thickness of thousands of metres—enough to make even the Himalayas feel small!

Current volcanic activity has thus built up gigantic mountains, the most awe-inspiring being the Mauna Loa in Hawaii rising to a height of 30,000 feet between its base submerged 16,000 feet below sea-level and its crater at an altitude of 14,000 feet.

Volcanic activity has likewise poured out thousands of cubic miles of lava in the form of basaltic or ignimbritic (1) "beds" spread over enormous surfaces; it has emitted and is still emitting colossal quantities of water vapour, carbon dioxide, sulphur dioxide and other volatile components without which the composition of sea water and of the atmosphere would be utterly different.

It is not only the composition, moreover, but in all likelihood the very existence of the oceans which is due to volcanic activity since this extracts gases from the magma—a process undoubtedly responsible for the existence of surface water and hence of life itself.

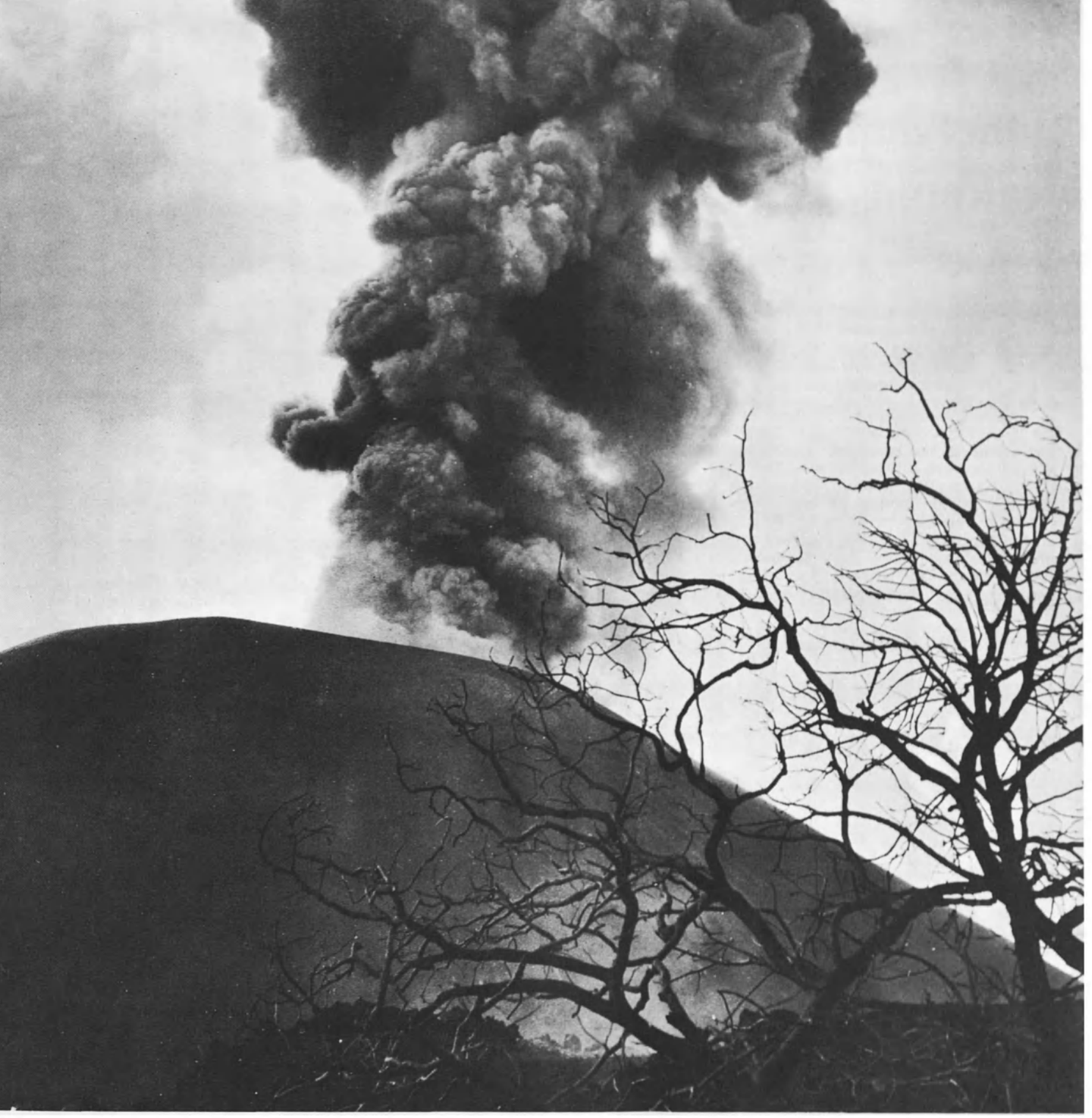
There is a third aspect which to peoples who inhabit the unstable regions of our planet is of even greater importance: the danger from volcanoes themselves.

Great volcanic catastrophes in which thousands of people are killed are relatively uncommon—one, two or perhaps three in a century, as far as we know and also allowing for the extreme shortness of recorded history; but disasters involving hundreds of victims are quite frequent.

In 1815, Tambora in the Indonesian island of Sumbawa was decapitated by a series of tremendous explosions which were *heard* 1,100 miles away; blocks of stone weighing several pounds were hurled for distances of over 25 miles; the mountain's height was reduced by 3,000 feet; 300 miles away, the island of Madura was plunged into complete darkness for three days, so thick and dense was the colossal canopy of ash which covered this part of the world; some 92,000 human beings and millions of domestic and wild animals died during this catastrophe.

Sixty-eight years later, in the same region, Krakatoa caused the death of more than 36,000 people; three-quarters of the island of Rakata with an area of 12 square miles

(1) *The problem of ignimbrites and ignimbrites themselves were only recently discovered. The term was created in* 1932 *by the New Zealand geologist Marshall from "ignis," fire, and "imber," rain, to signify the way in which highly silicic volcanic rocks are deposited over tremendous areas.*



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BORN IN A CORNFIELD. The volcano Paracutin was born with dramatic suddenness in 1943 in a Mexican cornfield. Beginning as a tiny crack in the ground, it spewed forth cinders, ash, lava and rock, growing 50 feet within 24 hours and reaching 1,000 feet within six months.

and an altitude of some 2,600 feet was shattered by explosions heard as far as Singapore and Australia, 2,500 miles away; pumice and ash were hurled to a height of over 120,000 feet; then enormous subsidences occurred in the subterranean hollow left by the eruption of cubic miles of lava; this subsidence created a submarine caldera, a cauldron-like cavity nearly four and a half miles wide, and provoked *tsunamis*, incorrectly called tidal waves, which, after devastating the coasts of the Sunda Straits, crossed the Pacific and were felt as far away as Chile.

The 20th century was only two years old when the Mt. Pelée disaster occurred, wiping out the town of St. Pierre de la Martinique and its 28,000 inhabitants. This eruption provided the scientific world with a new phenomenon which the French mineralogist, Alfred Lacroix, the first to study it, baptized "the fiery cloud."

This consists of a deadly combination of drops of molten lava, ash, sand and rocks of all sizes suspended in gases with a temperature of a thousand degrees. The explosion which frees this cloud generally goes sideways rather than upwards; it bursts through the weakest point in the side of a dome of highly viscous lava which the pressure of the gases forces slowly out.

Shooting out obliquely, the explosion then hurls its pulverised lava, rock and fiery vapour in a specific direction. The cloud rushes onwards, hurtles down slopes at speeds which may range from 50 miles per hour to over 180, leaps over natural obstacles such as ridges and sheer ravines which may be in its path and spreads death and destruction up to a distance of five or even ten miles (St. Pierre was five miles from Mt. Pelée; Merapi on the island of Java frequently causes deaths among the people living as far as five miles away in the valleys round its base).

In 1955-1956, a volcano which was thought to be extinct suddenly erupted with such fury that it would certainly

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Cataclysmic awakening

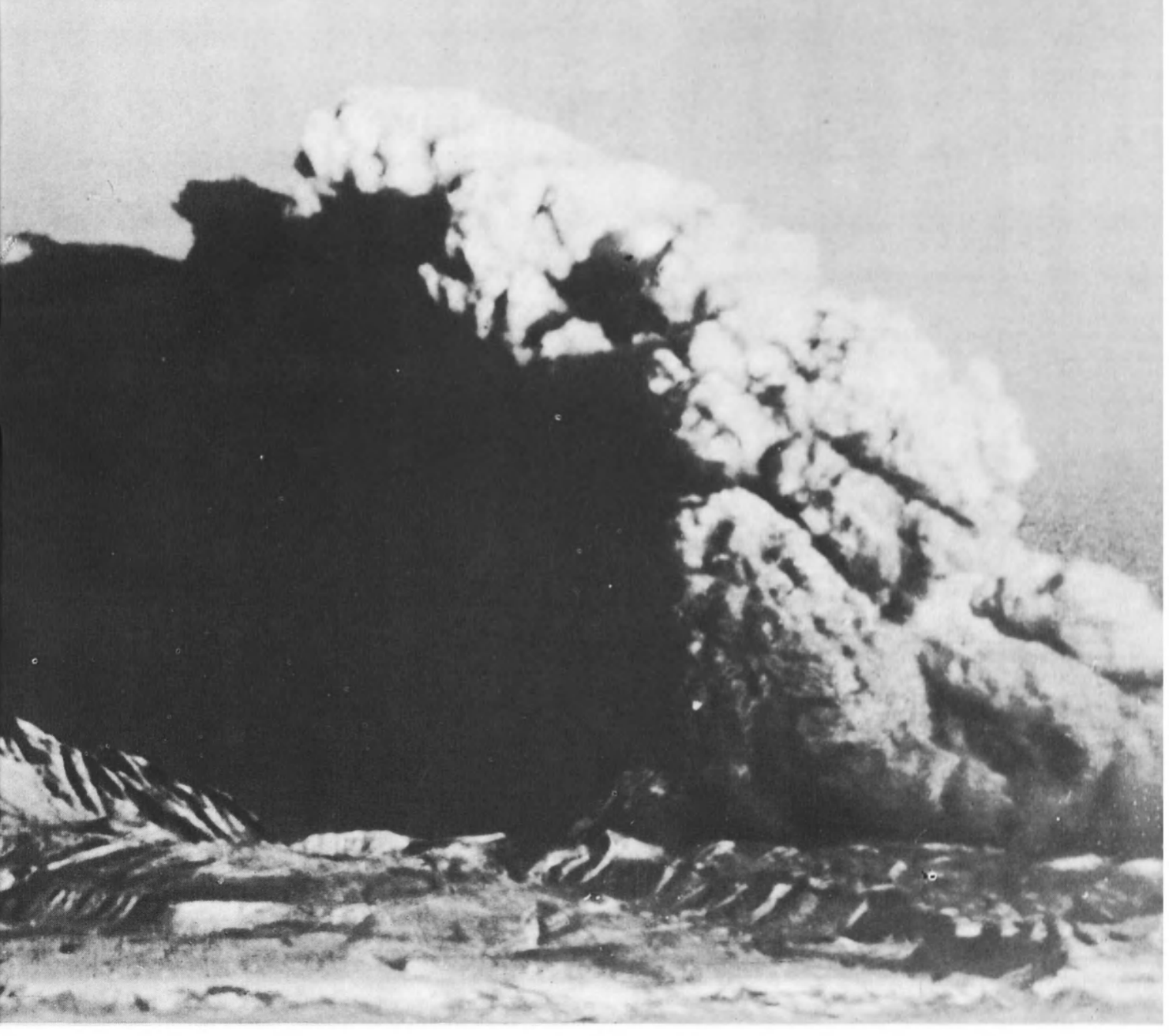
have caused scores and possibly hundreds of thousands of deaths if it had been situated in a more densely populated country. Fortunately there were neither deaths nor destruction since this volcano, Mt. Bezimiannyi (The Nameless Mountain), is in a desert area of the Kamchatka Peninsula.

The awakening of Mt. Bezimiannyi came with a violence proportionate to the length of its sleep. Figures provided by the Soviet volcanist, G.S. Gorshkov, who observed the eruption from the Klioutchi Observatory, give some idea of its cataclysmic power: energy unleashed: 2.2×10^{25} ergs; energy released by the most violent single explosion of March 30, 1956: 4×10^{23} ergs (40 million kw.-hours); volume of rock ejected by the explosion: 1 cubic kilometre (enough to bury Paris under a layer 50 feet thick); weight of debris ejected: 2,400 million tons; initial velocity of ejectments: between 1,650 and 1,970 feet per second (1,100 to 1,200 miles per hour); initial pressure: 3,000 atmospheres; altitude reached by the eruptive cloud: 150,000 feet.

By good fortune, the other great eruption of this century, the Katmai eruption of 1912, also occurred in a deserted region in the massive Aleutian volcanic range which extends onto the American continent via the Alaska peninsula. Its consequences were formidable: Mt. Katmai was completely decapitated and a caldera three miles in diameter appeared in place of the summit. Through fractures running right down to the mountain's north base, a fantastic quantity (12-15 cubic kilometres) of pumice was ejected. Powdered by the pressure of its own gases, it spread like a fiery cloud, filling a valley 12 miles long and three miles wide, thereby creating the ignimbrite of the famous Valley of Ten Thousand Smokes. Finally, an entirely new volcano, emerged and was named Nova Rupta.

AN ANGRY GIANT. One of the greatest eruptions of this century occurred in 1955 when Mt. Bezimiannyi (The Nameless Mountain), an "extinct" volcano in a deserted region of the Kamchatka Peninsular awoke in sudden fury (above). The cataclysmic power unleashed by this giant was astounding. It shot out 2,400 million tons of debris (enough to bury Paris under a layer 50 feet thick) at speeds of from 1,100 to 1,200 m. p.h. and carried the eruptive cloud to a height of 150,000 feet. Below, Soviet vulcanologists take a crater-lip look at another volcano in the Kamchatka region.

Novosti Press Agency



As in the case of all such major upheavals, the explosions were heard over great distances, sometimes as far as 600 miles off; ash covered many hundreds of square miles, plunging the village of Kodiak, 100 miles away, into darkness at noon. Even more extraordinary was the fact that tectonic earthquakes accompanied the eruption and were recorded by seismographs throughout the Northern Hemisphere. This was the first and only recorded eruption which produced ignimbrites.

The study of volcanic phenomena is rarely easy. Everything seems to conspire against those who seek to penetrate the mysteries. The terrain is *always* difficult and sometimes completely inaccessible. There is danger which is sometimes obvious and formidable and sometimes all the greater for being concealed. It is quite impossible to probe the depths of the volcano to find out what is happening inside. Finally, the complexity of the volcanic activities, intermingling in time and space, demands the simultaneous presence of specialists from all the scientific fields concerned in the investigation.

The time has passed when a single man such as Pliny the Naturalist, or investigators like Hamilton, Spallanzani; Perret or Lacroix, could individually harvest enough facts from their observations of an eruption to advance the sum of human knowledge. Nowadays when the recording of volcanic phenomena in ever more accurate figures is increasingly important, the work of studying active volcanoes has become essentially a team operation.

And merely to assemble a fully-representative group of specialists on or near a volcano in eruption is already itself a difficult undertaking, for except in Japan there are very few experts in vulcanology, and they are scattered throughout the world, each in his own institute or university.

To attempt to bring enough of them together, rapidly enough and at short notice, in response to the whim of a volcano situated in some remote spot is an almost hopeless task. It is for this reason that only very few eruptions have so far been observed with all the resources now available for taking the measure of all the multiple aspects of volcanic activity.

That the dangers are in no way imaginary is proved by the disappearance of twelve Japanese experts and twenty sailors who set out to investigate the submarine volcano of Myojin Syo during its eruption in 1952. After many days of fruitless searching, all that was found of the oceanographic ship (hundreds of miles to the southwest where they had been carried by the currents) were scraps of planking, some wooden objects and a buoy riddled with pieces of pumice-stone of obviously very viscous lava.

So far, it is only in Japan that eruptions have been studied by adequately-representative scientific teams. In other countries, problems of a practical kind (warnings against catastrophes, for example) are either relatively unimportant (in Italy, U.S.S.R., U.S.A., New Zealand, and certain Australian territories) or, where more acute

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Exploring a lake of molten lava

problems exist, the official attitude towards scientific research is unfortunately one of indifference.

Scientists can already forecast volcanic eruptions and will probably soon be able to predict their violence and hence the danger they present. But this is only possible in the case of volcanoes which, constantly observed and meticulously studied, thus become thoroughly familiar to the specialists responsible for forecasting disturbances likely to endanger the surrounding population.

In the few places around the world where there are properly equipped and efficiently staffed vulcanological observatories, it is now almost impossible for an eruption to take people by surprise.

But apart from these places—Asama-Yama, Aso-San and Sakurajima in Japan. Kilauea in Hawaii, Klioutchevskof in Kamchatka. Vesuvius and shortly, no doubt, Etna in Italy—nowhere else today are volcanoes kept under even the minimum supervision required to prevent catastrophes. Java, where the pre-war vulcanological service has remained intact, still lacks highly specialized teams, and a country which is in such danger from upheavals in one or another of its dozens of formidable mountains of fire needs more than the services of a few competent geophysicists. Much the same applies to the Philippines, the Lesser Sundas, the Antilles and to all the volcanic countries of Latin America.

Apart from Japan, it is in those regions where volcanic activity is either limited or utterly non-existent that, paradoxically enough, most of the world's volcanists are found today. And, it is equally paradoxical that in Western Europe, it is Belgium, a non-volcanic country, that has revived its vigorous pre-war research into active volcanoes.

It should be explained that the impetus for this development came from the former Belgian Congo where, in an area hardly more than ten miles by twelve, to the north of Lake Kivu, there are eight large volcanoes, some of them particularly violent. Eruptions are relatively frequent (ten in the course of half a century). However, by far the most interesting feature of this region is the deep Niragongo crater, which posseses the only lake of permanently molten lava existing anywhere in the world.

Lakes of molten basalt quite often develop during the eruption of a group of volcanoes but access to the area is often subject to the same dangers that are found in active craters. A permanent lake, however, provides an ideal subject for those probing the mysteries of volcanic activity: there is practically no danger and the basic matter of the volcanic action—molten lava and the gases it emits—is abundant if not readily accessible.

By managing to descend the 650 foot wall of the large caved-in crater of Niragongo which had discouraged earlier attempts at exploration, I had the good fortune to discover the existence of this lake, the only one of its kind in the world today. This was in 1948, after which ten years went by before it was possible to overcome the opposition of the Chairman of the Belgian Congo National Parks to any form of vulcanological research on Niragongo.

It was only in 1958 that the first reconnaissance and systematic expedition could be organized. The following year a larger and more comprehensive expedition was sent, in which Belgians, French and one Japanese scientist took part.

The approach to the Niragongo lava lake is much more difficult than was the case with Kilauea in Hawaii whose "fount of fire of Halemaumau" was rightly renowned throughout the world during the century preceding its disappearance in 1924. Unlike the case of Hawaii where it was possible to drive up by car to the very edge of the lake, the approach to Niragongo involves climbing a mountain almost 12,000 feet high, first following elephant tracks through the virgin forest and then clambering over the hard dark lava which crowns this powerful cone, abruptly truncated by the 3,600-foot wide crater.

Then comes the descent of the crater. Nearly 650 feet of steep and dangerously unstable wall divides the crest from the vast ring-shaped terrace which stretches out horizontally from the foot of the wall.

This terrace surrounds the central well which is some 1,500 feet across. To reach this point, a vertical wall nearly 600 feet high must be passed. The treacherously insecure rock which forms this wall would make it an excessively hazardous obstacle even for experienced mountain-climbers.

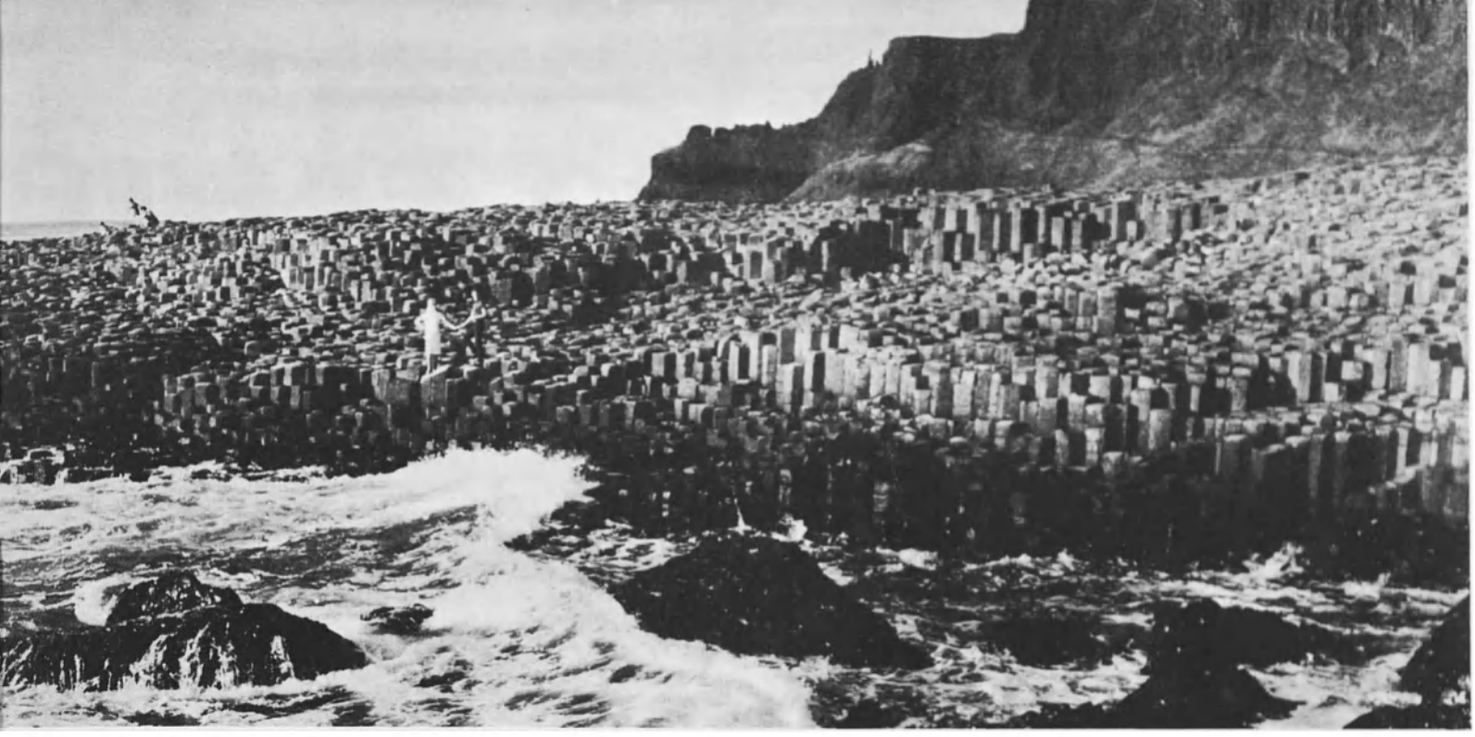
Accordingly, we had a light cave-explorer's winch built, and, suspended at the end of a thin steel cable attached to this winch, each of us descended in turn like a spider at the end of a strand of web, until we reached a second ring-shaped terrace only a few dozen yards across.

A tent was pitched there and for a month this was our advanced camp. Beyond this, a steep ledge measuring a good twenty yards was surmounted by means of duralumin ladders and we then made our way through a chaos of huge fallen boulders until we reached the opening of the narrow platform which, more than 1300 feet below the crest of the crater, encircles the vast lake itself.

Over the last ten years or so, the lake has shrunk appreciably, from some 320,000 square feet to roughly 140,000. Even so, it remains one of nature's most extraordinary spectacles. The great stretch of molten rock is sometimes calm, covered with a strange skin as plastic and shining as satin, then sometimes breaks out in currents, purple whirlpools and incandescent "fountains" scattering viscous magma over the steep banks on which we would stand in a wonder born of delight and awe which was felt even by the most matter-of-fact members of the team.

Here, cherry-coloured stalactites hung from the vaulted ceilings of fantastic fiery grottoes in which torrents of lava, suddenly quickening their pace, would be swallowed up; a rhythmical swell, like a recurring fever would sometimes seize the heavy liquid mass; there were sluggish orange-coloured surges in the more peaceful parts, and strange galleons of black rock on a sea of dark fire; there was a roaring, a rumbling, and sulphurous smells. All this helped to create around us a closed universe which was miraculous and almost terrifying.

In six weeks, this awe-inspiring, ever-changing splendour never once wearied or bored us. Nor, fortunately, did it distract us from our immense programme of work. Day and night for weeks on end, each specialist carried out his observations, made his measurements, analyses and recordings. The results of the seismology, the spectrography of the volcanic flames, the terrestrial magnetism, the gravimetry, the chemical composition of the gases, the mineralogy of the lava, the analyses of the sublimates, and the photogrammetry would probably not mean much



British Travel and Holidays Association

HEXAGONAL COLUMNS running in a promontory from the coast of Antrim in Northern Ireland are a remarkable collection of basalt rocks, some being 20 ft. in length, known as The Giant's Causeway. Distribution of basalt rocks, formed by the solidification of lava, is world-wide.

to anyone except a volcanist, but the figure for the heat radiated by this infernal bath—930,000 K.W.—speaks for itself.

It is far easier to reach the Italian volcanoes of Etna and Stromboli because they are situated in a country with a highly developed technology. But the final approach to the burning lava and the vents in order to collect samples of gases unmixed with pure air is, surprisingly enough, a much more hazardous operation than is the case at the spectacular Niragongo lake.

But the regular explosive activity of Etna and Stromboli offers experts in the seismology of volcanoes a promising field for exploration. The original team has expanded since 1958 and is now made up of Italians, Frenchmen and Belgians. Soon English scientists will be joining it and later on, specialists from Finland, Hungary and elsewhere.

The primary aim of this physically fatiguing and often baffling research, is to understand the hows and whys of volcanic activity. For these powerful terrestrial phenomena are far more vast and much more important than the superficial movement of lava, however spectacular and even deadly this may be.

As Alfred Rittmann, one of the outstanding volcanists of our century, so aptly put it, "volcanic activity is a process at work both within and below the earth's crust, a process in which the liberation of gases from the crude magma plays a rôle of primary importance in the history of our planet's development" (1).

Rittmann drew up a vast synthesis in which he showed how the earth has evolved from the original solar matter, how the granitic continents were formed, how the primitive atmosphere and ancestral oceans were created—all through the liberation of gases, the differentiations, the movements involved in or caused by the magma. He showed how the upsetting of balances, balances of temperature, balances of weight, physical or chemical balances, have throughout the four thousand million years and more of the earth's existence caused, as they still do, massive shifts within that magma, currents which mix it in an attempt to restore the upset balance and thereby exercise their colossal power on the crust of the earth.

It is in this way that the deep oceanic deeps are formed, folds in the thin crust of basalt which forms the ocean beds; sometimes these deeps develop into geosynclinals in which sediment brought by the rivers from the neighbouring continent accumulate to a depth of thousands upon thousands of yards. And it is from these geosynclinals, after a complex process of evolution lasting millions of years, that the great mountain ranges—Alps, Andes and Himalayas—emerge.

The whole of this vast orogenic process is due to the movements of the magma, the same movements which, when they break through the earth's crust at the points of extreme pressure, allow the magma to rise and to burst forth at the surface, thereby causing volcanic activities in the narrow sense of the term.

It is in this way that we must consider volcanic activity if we genuinely seek to understand its significance: as a cosmic phenomenon which shapes the face—and the depths—of the earth and in which eruptions are no more than a superficial aspect.

This fascinating side to volcanic research may strike some people as somewhat irrelevant and even excessively speculative; yet it is an essential ingredient for progress in the two utilitarian aspects of vulcanology: the forecasting of dangerous eruptions and the harnessing of the formidable power of volcanoes.

As already pointed out, we may be able to foresee the imminence of an eruption empirically but we cannot yet predict either its violence or its duration, and without these factors we cannot decide on the urgency and the extent of the precautions to be taken. We shall, however, attain a sufficient degree of accuracy when the true mechanism of the phenomena is known, at least to a greater degree than is achieved by the rough hypotheses now employed.

Similarly, it is through fundamental knowledge that we will be able to develop—and certainly in a very spectacular fashion—the exploitation of geothermic energy. Today this new source of power has only begun to be tapped, although already it has given magnificent returns, at Lardarello in Texas and at Wairakei in New Zealand. Tomorrow, California and Kamchatka will benefit from the millions of kilowatts recovered from those so abundantly provided by volcanoes. And this inexhaustible source of cheap power will assuredly be one of the most productive throughout the world of the future.

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(1) *A. Rittmann: "Les Volcans et leur activité," revised and expanded edition, Masson, Paris,* 1963.

HAROUN TAZIEFF, *Belgian geologist and vulcanologist, is the author of many books on geophysics. He has produced several prize-winning scientific and documentary films on volcanic eruptions.*

300,000 EARTH

by E. M. Fournier d'Albe

Visitors to a famous seismological observatory in Australia are sometimes told a strange and sad story:

Some years after the end of the First World War, an eminent Japanese scientist was visiting Australia and was taken to see this observatory. The director received him with due ceremony, and then led him down to the underground vaults where, in the darkness, the seismographs were keeping their constant watch. The director switched on the light in the vault. In those days, the recordings were made mechanically, by thin steel pens on smoked paper; (now it is more common to record on photographic paper by means of a light beam reflected from a galvanometer, and the vault has to be kept in permanent darkness).

The visitor from Japan could see three instruments, each one standing on a concrete pillar about a metre high. In a corner, a large clock was ticking in a complicated manner. The director showed him that in each instrument there was a heavy weight suspended on strong springs; this weight, by its inertia, would set the pen of the instrument moving whenever the slight tremors from a distant earthquake reached the observatory. In one of the seismographs, the weight was suspended in such a way that it could move vertically up and down; in the other two, it could only move horizontally, in the East-West direction in one instrument and in the North-South direction in the other.

The visitor was examining the latter, when quite suddenly the pen began to swing slowly from side to side, leaving a wavy trace on the black surface of the recording paper, where before there had been only a series of straight lines.

"That's a bit of luck," said the director, "It's working specially for you. It isn't often one sees an earthquake actually being recorded."

The pens of all three instruments were now moving, but the movement on the North-South instrument was slightly greater than that on the East-West one.

"These are the compression waves, or P-waves for short," said the director. "If you would like to wait a few minutes, we shall perhaps see the arrival of the S-waves—the transverse, or shear, waves. Then we shall have an idea of how far away this earthquake has occurred."

A few minutes later, the director exclaimed "Here they come!" The visitor could hardly see any difference in the movement of the pens, but the director pointed out to him that now the movement on the East-West instrument was greater than that on the North-South one.

"It's quite a long way off, probably to the north of us," said the director. "But it's a big one! Let's go up to the office. I'll look up the travel-time tables and give you a rough estimate of the distance. You see, the P-waves travel faster than the S-waves, so that the time-lag in the arrival of the latter gives an indication of how far away the earthquake is. But I can only give you a rough estimate, of course. To locate an earthquake accurately, one has to combine the readings of a large number of observatories."

It did not take the director long to work out the distance: "About 10,000 kilometres, I should think. That probably means Japan or the Aleutians."

In fact, it was Japan, for this tremor was recorded on September 1, 1923, the date of the Great Kanto Earth-

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Carl Mydans, Courtesy Life Magazine © 1963, Time Inc.

QUAKES A YEAR

LAST INSTANTS. This remarkable photograph of a swaying building only seconds before it collapsed was taken when an earthquake struck the Japanese city of Fukui in 1948. Earthquakes are known to be concentrated in two chief belts. Some 80% occur along the rim of the Pacific Ocean; another 15% take place in a band extending from North Africa through Southern Europe, the Alps and Asia Minor to India and Burma, then joining the Circum-Pacific belt in Indonesia.

Mapping the danger zones

quake which ravaged Tokio. It was not until later that the director learned that five members of his visitor's family had been killed in this earthquake.

It has been estimated that over 300,000 earthquakes occur each year, but relatively few are strong enough to be felt by the population in general. Nevertheless, since the beginning of this century earthquakes have, on an average, killed over 15,000 persons and caused hundreds of millions of dollars worth of damage each year. Some countries such as China and Japan, Chile and Peru, Italy, Greece, Turkey and Iran, have suffered far more heavily than others.

In fact, earthquakes tend to occur repeatedly in certain well-defined zones stretching around the world. The first of these is the Circum-Pacific zone, which extends all round the shores of the Pacific Ocean from Chile to New Zealand. The second is the Mediterranean-Alpine zone, which stretches from Morocco in the West, through the Mediterranean and along the mountain chains of the Caucasus, the Hindu Kush, the Karakoram and the Himalaya into China, Burma and Indonesia.

In order to see how the geography of earthquakes has been discovered, we must go back to the seismological observatories and find out what happens to the data recorded by the instruments there.

There are now over four hundred observatories installed in different parts of the world, many with instruments far exceeding in sensitivity those which the visitor from Japan saw in 1923. But, however sensitive the instruments employed, it is still impossible for one single observatory to locate an earthquake. In order to do this, the data from many observatories have to be collected and analyzed together. This is done at two national and two international centres.

WORLD'S FIRST SEISMOGRAPH

WHEN an earthquake occurs, observatories which have recorded it send immediately, by telegram or airmail, their readings of the P and S-wave arrival times to the United States Coast and Geodetic Survey in Washington, or to the Institute of Earth Sciences in Moscow, or to both. These centres then make what is called a preliminary determination of the earthquake epicentre (that is to say, the point on the earth's surface vertically above the focus of the earthquake, which may have occurred tens or even hundreds of kilometres below the surface.)

With this preliminary determination to help them, the staff at each observatory examine their records again and make a more complete analysis of them for inclusion in the observatory bulletin which is usually published once a month. This bulletin is sent to other observatories, in exchange for theirs, but it also goes to two international centres: the *Bureau Central International de Séismologie* in Strasbourg (France); and the office of the "International Seismological Summary" in Kew (England).

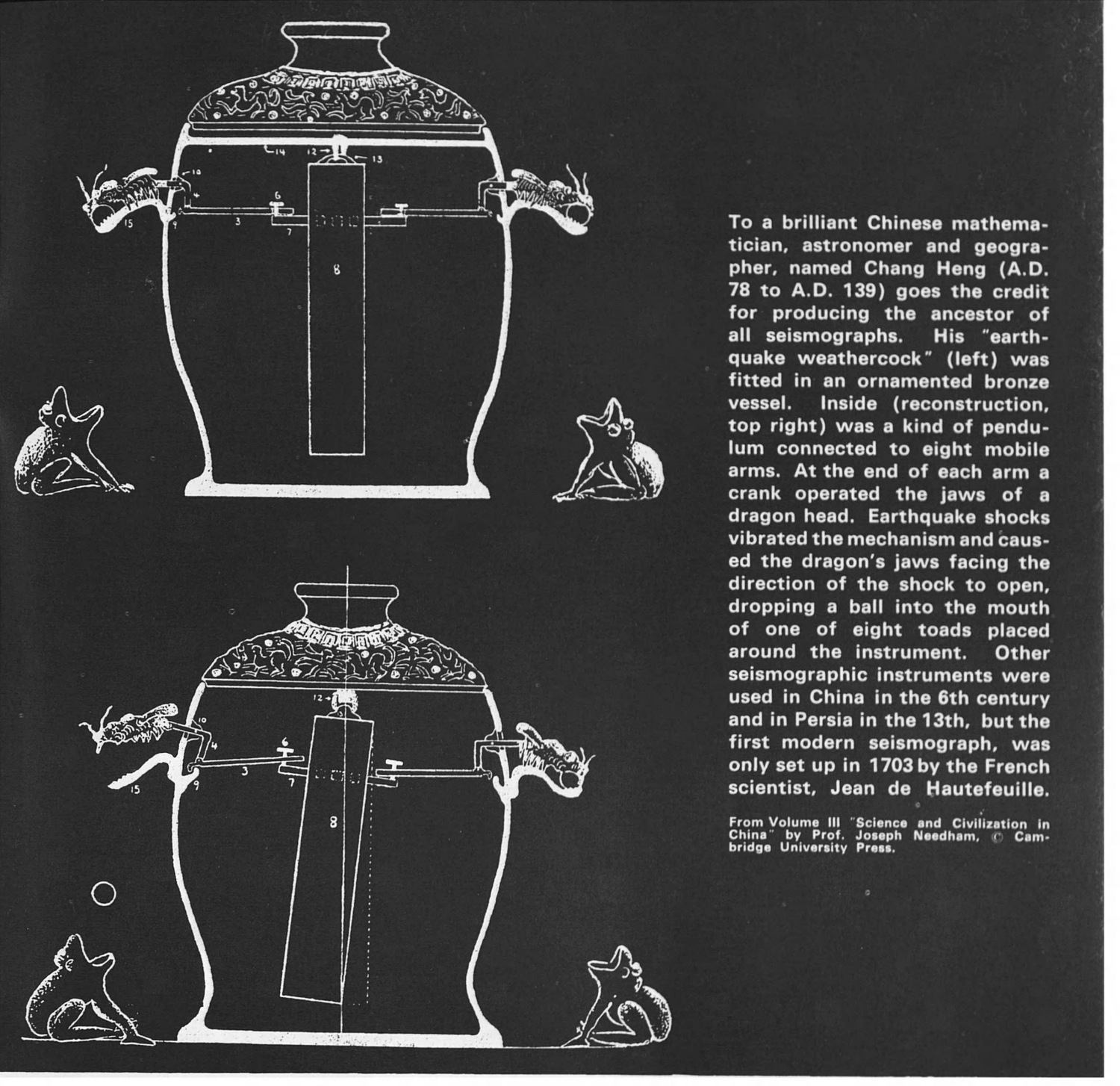
The first of these centres makes an accurate determination of the earthquake epicentre and depth, using the data from as many observatories as possible. Nowadays, this Bureau's Annual Bulletin runs to over 2,000 pages and may contain data on over 60,000 earthquakes recorded each year (of course, only a few of these are strong enough to be felt or to cause damage.) The International Seismological Summary makes a more detailed analysis of certain selected earthquakes, and the results of its work are used mainly in research on the interior of the earth.

From the study of this immense volume of data, the pattern of distribution of earthquakes over the earth has now emerged quite clearly, and some insight has been gained into their causes which are probably linked with the slow convective movement of material in the earth's mantle. From the practical point of view, even more interesting results come from the study of the distribution of earthquakes within certain limited regions, such as Southern Europe, Central Asia or California.

When the seismicity and the geology of a region are studied together, there sometimes emerges a detailed pattern of earthquake activity which is not only of scientific interest, because of the light it sheds on the mechanisms involved, but is also of great practical value, because it permits a delimitation of the zones in which earthquakes are liable to occur. Sometimes, a few kilometres or tens of kilometres will make an appreciable difference to the maximum intensity of earthquakes that can be expected.

This knowledge is extremely useful, and it may even in some cases determine the choice of site for a dam, a power station, a factory, or a new town. More often, however, other factors have overriding importance and building must go ahead in certain places regardless of the earthquake danger. This is where the specialist in earthquake engineering comes in.

The 1923 earthquake in Tokyo, with which we began this article, is famous for the fact that a number of large buildings, which by rights should surely have been destroyed, actually withstood the shock and suffered very little damage. They survived because they had in fact been designed to do so, but this was the first time that a public demonstration had been given so clearly that



To a brilliant Chinese mathematician, astronomer and geographer, named Chang Heng (A.D. 78 to A.D. 139) goes the credit for producing the ancestor of all seismographs. His "earthquake weathercock" (left) was fitted in an ornamented bronze vessel. Inside (reconstruction, top right) was a kind of pendulum connected to eight mobile arms. At the end of each arm a crank operated the jaws of a dragon head. Earthquake shocks vibrated the mechanism and caused the dragon's jaws facing the direction of the shock to open, dropping a ball into the mouth of one of eight toads placed around the instrument. Other seismographic instruments were used in China in the 6th century and in Persia in the 13th, but the first modern seismograph, was only set up in 1703 by the French scientist, Jean de Hautefeuille.

From Volume III "Science and Civilization in China" by Prof. Joseph Needham, © Cambridge University Press.

buildings, if properly designed and constructed, need not necessarily collapse and kill their occupants during a severe earthquake.

Since 1923, research in the design of earthquake-resistant construction has made further progress, particularly in Japan and the United States. The general principles behind successful design appear to be firstly, to hold the building together as a single structural unit, and secondly, to design it in such a way that its natural frequency of vibration does not correspond to the frequencies of the earthquake waves. Different building materials demand different techniques, but it is probably now true to say, in general, that if people are killed *in* earthquakes it is not *by* the earthquakes themselves but rather by inadequate building.

"Everybody talks about the weather," said Mark Twain, "but nobody does anything about it." In one sense, there is not much one can do about earthquakes: there is certainly no means of stopping them. However, a lot is being done to make them less dangerous. Although we are still very far from being able to forecast *when* earthquakes will occur, the patient accumulation of observations is making it possible to define more accurately the zones *where* the danger exists. Within these zones, the risk to human life and property can be greatly reduced by the proper application to the design and construction of buildings of principles which are already well established.

So long as people still die in earthquakes, research and education in seismology and earthquake engineering must continue with all speed. The network of seismological observatories must be improved, the accurate mapping of earthquake danger zones must be extended to cover the whole world, adequate design and construction of buildings must be ensured and young scientists and engineers must be trained to become specialists in these subjects.

Seismology is, *par excellence*, an international science, for earthquakes are no respecters of national boundaries. The saving of human life is everyone's concern. These are two reasons why UNESCO has become involved in seismology. Its job is not only to make easier the collaboration of scientists and engineers from different countries, but also to speed the flow of knowledge and skills from the great research centres to those people, in all countries, who have the responsibility for putting this knowledge to good effect.

DR. E. M. FOURNIER D'ALBE *is programme specialist in seismology and geophysics for Unesco's Department of Natural Sciences. He has carried out long-term missions for Unesco in Mexico and in Pakistan, where he helped to set up a geophysical observatory in the earthquake-prone region of Quetta.*

EMERGENCY QUAKE SERVICE

Unesco plans to set up a 24-hour seven-day-a-week earthquake service at its headquarters in Paris which will be able to call upon experienced seismologists and earthquake engineers to arrive on the site of major earthquakes as quickly as feasible anywhere in the world and wherever possible at least within 72 hours of their occurence. Special arrangements are being made with the leading seismological centres in the U.S.S.R., U.S.A. and other countries to inform the Unesco Earthquake Service of all major quakes.

Is is important that seismologists and earthquake engineers arrive on the spot as soon as possible after a big shock. At the request of the respective Governments, Unesco sent experts to Iran, Libia and Yugoslavia very soon after the recent earthquakes in those countries to make on-the-spot studies and to advise local authorities on protection measures to be taken against possible future earth tremors.

Years of disaster

During the first quarter of the 20th century, half a million people were killed by five major earthquakes—San Francisco (1906), Messina (1908), Arezzano (1915), Kansu (1920) and Tokyo (1923). In the next twenty-five years, records kept by the International Bureau of Seismology at Strasbourg showed that on an average 14,000 people were killed annually. Peak years were 1927 (76,615 deaths), 1932 (78,202) and 1939 (61,082). China is the country which has suffered most from earthquakes. It experiences shocks of great intensity in areas especially prone to landslides.

World-wide survey

The study of earthquakes—a field in which progress depends on international co-operation—is a major feature of Unesco's science programme today. A broad picture of the present status of seismology in different countries has been obtained through a series of Seismological Survey Missions sent out between June 1961 and May 1963 by Unesco in consultation with the International Union of Geodesy and Geophysics, and personally led by the president of the International Union, Professor V.V. Beloussov or by Prof. J. P. Rothé, Secretary-General of The International Seismological Association. The first of the missions visited 15 countries in South-East Asia, the second toured seismic regions of Latin America, the third went to countries of the Mediterranean and Middle East regions and the fourth made studies in Africa. The aim of these missions was to examine the state of seismological and geophysical observatory networks, the progress made in locating and mapping seismic zones, the application of special regulations concerning earthquake-resistant design for buildings and, finally, the resources available for training specialists in seismology, seismo-geology and earthquake engineering. Next year Unesco will convene an intergovernmental meeting to study the general development of seismology and earthquake engineering.

Volcanoes to watch

Following a series of eruptions by Mount Agung on the island of Bali early this year, when 1,460 people were killed and 53,700 hectares of paddy fields devastated, Unesco sent a team of experts to the island. These experts have recommended that a permanent vulcanological observatory be set up on Mount Agung and ultra-sensitive seismic recording instruments installed to keep watch over this earthquake-prone area. Similar observatories are needed to keep an eye (and an ear) on the rest of Indonesia's 127 active volcanoes.

More seismologists

A map of the epicentres of the main earthquakes shows that the most severely-stricken regions are very often in territories now in the throes of economic development. Large scale engineering works are being undertaken, factories are being built and cities are expanding. All this progress may be wiped out in a few minutes if construction sites are badly chosen or if proper measures of protection are not taken in advance. Yet these are the countries with the fewest specialists in seismic matters. The United Nations Special Fund, acting through Unesco, has offered 67 fellowships for study at the International Institute of Seismology and Earthquake Engineering set up with Unesco's help last year in Tokyo.

The right materials

Certain building materials lend themselves better than others for earthquake-resisting construction. It has been shown that masonry walls reinforced with concrete slabs, reinforced concrete frames and steel frames are most likely to resist earthquakes. However more research is needed into possible uses of local materials (wood, bricks, mud walls, etc.). Poor construction (excessively heavy roofs, facades not anchored to the foundations, weak timbers) is often the real reason a building collapses.

Price of security

Contrary to popular belief, the design and construction of earthquake-resisting buildings (except very tall ones) are easily met at relatively little extra cost. But it is wiser to eliminate parapets, cornices, balconies and similar decorative elements which are often responsible for casualties. To make the tall buildings in business sections of large cities earthquake resistant does involve additional cost, but this is relatively small in relation of the total cost of construction, and the protection and security obtained.

Measuring from space

Earth satellites in orbit, already used to study the shape of the planet, make it possible to measure great distances with a hitherto unattainable accuracy. Scientists now hope that it will thus be possible to obtain confirmation or invalidation of the theory of continental drift (see page 7).

© Europress

by Kenzaburo Takeyama

WANTED:

Courtesy Prof. K. Takeyama

SPECIAL STRUCTURAL DESIGN of the 40-story Latino-Americana Building in Mexico City brought it unscathed through the earthquake which struck the Mexican capital in 1957.

HEAP OF RUBBLE is all that remains of a multi-story building, its floors shattered and piled in concertina-like layers by last July's earthquake in Skoplje, Yugoslavia. Less than one-quarter of the city's 35,000 buildings can be repaired. Skoplje, a city of 220,000 inhabitants covering 70 sq. kms., was seriously damaged by quakes on two other occasions—in 518 A.D. and 1904.

MORE QUAKE-PROOF BUILDINGS

In 1906, more than half a century ago, a young Japanese building engineer visited San Francisco in the wake of the disastrous earthquake that had wrought havoc in the city. He was deeply impressed by a reinforced concrete structure he saw standing among a charred stretch of ruined brick buildings. It was unscathed either by the earthquake or by fire. Reinforced concrete buildings were becoming popular in Europe and the United States, but in Japan, only one building using this modern technique had been completed in the previous year.

Firmly convinced that this was the best antiseismic construction, the Japanese engineer, Riki Sano, returned home and devoted himself to developing the construction of reinforced concrete buildings in Japan and the study of earthquake-proof structures. Sano thus laid the foundations for the study of earthquake engineering in Japan.

Sano's work was continued and further developed by his pupil, Tachu Naito. An interesting tale explains how Naito came to develop his own theory of earthquake-proof construction. While visiting the United States to study reinforced concrete buildings, he one day had his suitcase smashed when it was thrown rather violently from a train to a station platform. Naito bought a new suitcase with partitions in it. When he saw that his new bag withstood many severe shocks yet still retained its original shape, he hit upon the idea of designing a building as "a box partitioned with several floor slabs and wall slabs." On the basis of this idea, Naito developed a theory of earthquake-proof construction and designed a number of buildings applying this technique.

It was after these buildings were completed that the Great Kanto Earthquake of 1923 struck the Tokyo area. Some 250,000 houses were destroyed, about 450,000 houses burned down and approximately 140,000 lives were lost. While the violent earthquake felled or severely damaged most of the multi-story buildings in the city all of Naito's constructions survived the tremor undamaged, thus proving the validity of his theory. Together with Naito's buildings, the Imperial Hotel, a lower, three-story structure, designed by the famous American architect Frank Lloyd Wright withstood the harsh trial of nature, and won world wide attention.

This disastrous earthquake greatly stimulated Japanese construction engineers in the study of earthquake-proof structures. They were given more opportunity to experiment and improve their theories and antiseismic engineering techniques when a number of big tremors hit other parts of Japan following the Kanto Earthquake. These studies bore fruits in the form of steel reinforced concrete construction (a structure with a steel frame in the core and reinforced concrete enveloping it) which is almost without exception applied to the construction of buildings higher than five stories in Japan today.

Thus Japan's earthquake-proof constructions have developed from the costly lessons of natural disasters and the theories arising from these experiences. However, other new theories of earthquake-proof construction were being developed using an entirely different process. For this, we must turn to the United States.

In California, the major earthquake zone of the United States, seismological observations grew in scale beginning around 1925. The Long Beach (California) earthquake of 1933 which claimed 140 lives provided a major stimulus to the research of earthquake-proof structures. One of the positive outcomes of the studies stimulated by the earthquake was the development of a strong-motion seismo-

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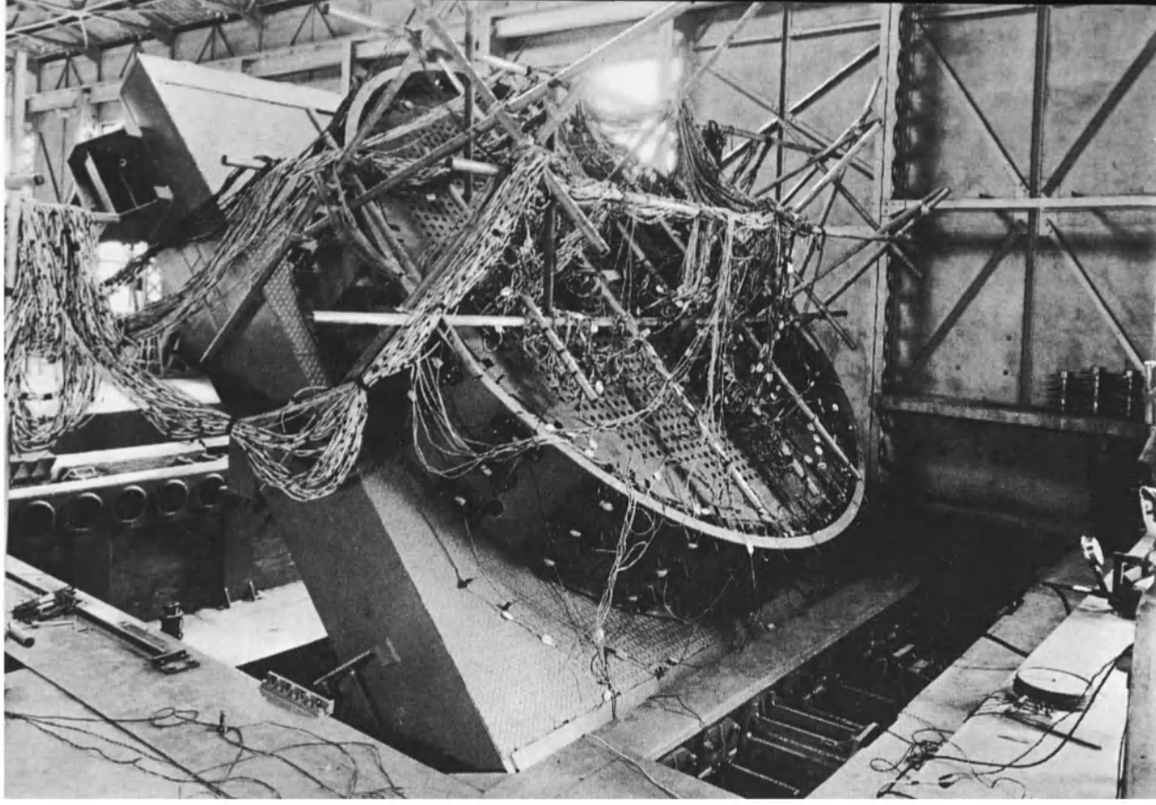


QUAKE-GENERATOR : *Artificially created earth tremors are supplied by this unique quake-generating table at the Japanese Government Building Research Institute in Tokyo. Capable of simultaneous horizontal and vertical vibrations, the machine is being used here to test the resistance to quake shocks of the core of an atomic reactor. Earthquake damage to a nuclear power station might cause the release into the atmosphere and the ground of radioactive material which could not only contaminate the immediate area but also spread over great distances.*

Courtesy Prof. K. Takeyama

QUAKE-PROOF BUILDINGS *(Cont'd)*

Test-bench for seismic disasters

graph designed to record the tremors of big earthquakes. Work on this strong-motion seismograph observation is still being continued today. Records taken in this way have greatly contributed to the advancement of earthquake-proof engineering research.

Actually, it had been impossible until recently to compute the behaviour of a building being shaken by the irregular vibration of the earth caused by an earthquake. Earthquake engineers were compelled to calculate by shifting the irregular earthquake waves into regular ones but the results obtained by this process were unreliable. However, in 1950, G.W. Housner of the California Technological Institute succeeded in determining how a building reacts to earthquake waves, by feeding actual records of a major earthquake and the theoretical model of a building into an analog computor which was developed during the last war. This epochal development marked a major breakthrough in earthquake-proof engineering research and opened up a new field.

Recovering from the damages of war, Japanese scientists designed and constructed strong-motion seismographs on their own, and installed 120 of them in various parts of Japan by 1960. Electronic computors too came into gradual use, and the antiseismic designing of buildings, hitherto developed in Japan on the basis of experience, is now being tested in the light of this new technique born of a modern scientific calculating machine. Ironically, however, since the strong-motion seismographs have been installed in Japan, the country has not been hit by a major earthquake although many disastrous ones have occurred in other countries.

These new developments in earthquake-proof engineering have taken place not only in the United States and Japan but also in other earthquake-prone countries, especially in the Soviet Union. As an outcome of advanced earthquake engineering, a trend toward relaxing the height limit imposed on buildings is being observed today in most countries that are liable to earth tremors.

One building which has provided an invaluable stimulus in the development of earthquake-proof engineering is the 40-story Latino Americana building in Mexico City which was unharmed in the earthquake of 1957.

A great problem facing earthquake engineers today is that while multi-story buildings are being made more and more earthquake-proof, residential houses have remained as vulnerable to earthquakes as they were years ago. Still fresh in our minds is the violent tremor west of Teheran, Iran, which destroyed 3,000 houses and took 13,000 lives in September 1962, and the even more recent disaster at Skoplje in Yugoslavia where 85% of the buildings were destroyed by a severe shock on July 26 this year.

Generally speaking, residential houses in these earthquake countries have no resistance whatsoever against the earthquakes because they are usually made of brick or adobe (sun burned clay). If a violent earthquake hits a heavily populated city in Southeast Asia where the houses are made of wood, a disaster similar to the 1923 Kanto Earthquake may be repeated.

Studies of ways to make wooden and brick buildings earthquake-proof have advanced most in Japan because of her repeated history of earthquake-fire calamities. Research on the development of earthquake-proof, fireproof and inexpensive constructions has progressed rapidly since the end of the last war. Most impressive is the big quake-generating machine used in the Building Research Institute of the Japanese Government to test the seismic resistance of buildings of two to three-story concrete-block structures or prefabricated reinforced concrete buildings.

No less useful is a large quake-generating table recently developed at the same institute for antiseismic tests. This table is unique in that it can give both horizontal and vertical vibrations simultaneously. Similar vibration-generators have been set up by other research organizations in Japan, the United States, Italy, India and other countries recently and are used to test the seismic resistance of arch dams and other structures as well as buildings.

There are moves in many countries to make residential houses as well as high buildings earthquake-proof. But mainly for economic reasons many of the lands where earthquakes occur most frequently have made little progress in this direction. In addition, these countries have very few seismologists and earthquake engineers and basic observation of earthquakes has yet to be done.

In an attempt to remedy this situation, UNESCO has established the International Institute of Seismology and Earthquake Engineering in Tokyo, expanding a programme started by the Japanese Government a few years ago. With the assistance of the United Nations Special Fund, a project has been to invite trainees from earthquake-prone countries to conduct joint research with specialists from all over the world.

It is hoped that this international project will hasten the day when people of all countries threatened by earthquakes are protected against these natural calamities.

DR. KENZABURO TAKEYAMA *of Tokyo Municipal University is counsellor to the International Institute of Seismology and Earthquake Engineering, Tokyo. He is also a former director of the Building Research Institute, Ministry of Construction, Tokyo.*

Letters to the Editor

HEBREW TRANSLATIONS

Sir,

In THE UNESCO COURIER (Feb. 1963) you published a very interesting article by Robert Collison: "The Continuing Barrier: Translations and East-West Communications." I think that the analysis of the *Index Translationum* from the point of view of East-West cultural communications is most valuable, and its results deserve close attention by UNESCO as well as the countries concerned.

However, I was somewhat surprised that Israel and the Hebrew language are not included in this article, in spite of the fact that our country is classified by UNESCO as Asian. We contribute regularly to the *Index Translationum* and a breakdown of the items we delivered to volumes 13 and 14 can be seen in the table below.

You will note that the number of translations into Hebrew is considerable in comparison with the numbers you give in Table 1 of the above article. Of course, these translations are destined primarily for readers in Israel. The bibliographical journal, *Kirjath Sepher*, published by the Jewish National and University Library pays special attention to all the translations into Hebrew.

It would be interesting for your readers to know that since the beginning of 1962 there exists an institute for the translation of Hebrew literature into other languages, for the special purpose Mr. Collison mentions in his article, i.e. to acquaint other countries and peoples with Hebrew literature in various subjects.

Dr. C. Wormann
Director, The Jewish National and University Library
Jerusalem, Israel

BOOKS TRANSLATED INTO HEBREW FROM THE FOLLOWING LANGUAGES:

Index Translationum	*Vol.* 13	*Vol.* 14
English	236	252
German	51	40
French	38	37
Yiddish	30	22
Russian	21	30
Polish	7	4
Italian	6	6
Classical Greek	4	2
Spanish	4	—
Danish	3	3
Arabic	3	8
Chinese	3	—
Roumanian	3	—
Bengali	3	—
Aramaic	2	1
Japanese	2	1
Hungarian	2	2
Swedish	2	4
Sanskrit	1	—
Latin	—	5
Dutch	—	1
Original language not identified	6	3
	427	421

BOOKS TRANSLATED FROM HEBREW INTO THE FOLLOWING LANGUAGES

English	53	73
Yiddish	13	12
French	9	6
Arabic	2	—
Portuguese	1	—
Spanish	1	3
Russian	1	—
Hungarian	—	2
German	—	1
Roumanian	—	1
	—	—
	80	98

SELECTED SCIENCE FICTION

Sir,

I very much enjoyed and strongly support the views of Arthur C. Clarke as expressed in his article "In Defense of Science Fiction" (November 1962).

I feel however that he, and you, missed an opportunity to promote much greater acceptance of these views when he wrote "Many... point out that 90% of science fiction is rubbish..." and failed to give us a much wider reading list from the healthy 10%.

Could we have a few more titles please?

Harry Wilkinson,
Cooksville, Ont. Canada

Ed. note: Arthur Clarke writes: "My statement that 90% of science fiction is rubbish, is intended as a compliment to science fiction, because probably 95% of general fiction is rubbish!

For me to draw up a reading list is liable to get me in hot water with my fellow practitioners. I would, therefore recommend anyone interested in the field to first get hold of Kingsley Amis' book of criticism, "New Maps of Hell." This gives a very amusing survey of the field and lists most of the worthwhile recent books.

Four outstanding volumes which should be fairly easily obtainable are "A Canticle for Leibowitz" by W. Miller "A Century of Science Fiction" edited by D. Knight, "A Case of Conscience" by J. Blish, and "The Space Merchants" by F. Pohl and C. Kornbluth. I would also recommend any anthologies edited by G. Conklin, F. Pohl, D. Knight, A. Boucher, and J. Merrill.

I would stress again that this list excludes much of the best work of the current writers. However, some of this is so advanced that to recommend it would be like offering James Joyce to a beginner in English.

Much good work appears in the leading science fiction magazines, viz. "The Magazine of Fantasy" and "Science Fiction," "Galaxy," "Analog" (U.S.) and "New Worlds" (U.K.). Several of these have foreign language editions which publish stories by local writers. The French fiction is a notable example.

HELPING SKOPLJE RISE AGAIN

Sir,

The terrible earthquake which recently struck the capital of Macedonia is not only a great ordeal for the Yugoslav people; it is a tragedy which has aroused the sympathy of the entire world. Assistance has been sent from all parts and there is no doubt that the city will rise again. It has been announced that the Yugoslav Government has decided to rebuild Skoplje on a new site. It seems to me that all the Member States of the United Nations should share in planning this new city and that each one should undertake to construct one of its streets. A city built in this way would be a magnificent monument, commemorating the victory of life over death and the solidarity of mankind.

Would you please bring this suggestion to the attention of those responsible for seeing that Skoplje rises again from out of its ruins.

Damian Damianov
Pernik, Bulgaria

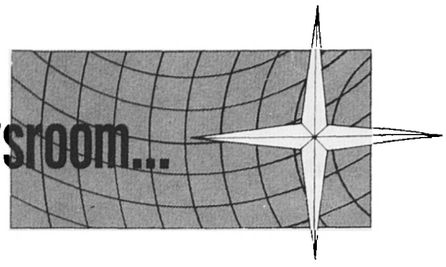
USE NATURE'S WEAPONS

Sir,

In the highly developed countries, contagious diseases have been replaced by "diseases of civilization" due to the denaturalized foodstuffs which people eat today. Why cannot we make greater use of biological methods in the battle against parasites instead of chemical substances which not only threaten human health, but also cause great ravages among insectivores, especially birds? In Switzerland, two doctors have set up a foundation with the aim of substituting efficient natural weapons for the chemicals now used to excess in agriculture. The use of the red ant in the fight against the bistrychides (bugs which damage trees) is one example of this use of natural weapons.

Helga Weiss
Zurich, Switzerland

From the Unesco Newsroom...



HARDWORKING HEART: How many times does a human heart beat in a day? On the average, more than 100,000 times according to a survey made by the University of Chicago. The heartbeats of men aged 16 to 60 were measured during a 24-hour period with a new heartbeat counter about the size of a packet of cigarettes.

THE WAY TO COMMUNAL HARMONY: Throughout his life Mahatma Gandhi pleaded the cause of better understanding between individuals and communities, teaching that the individual must rise above fear, jealousy and hatred. Many of his reflections on problems that divide nation from nation and man from man have now been collected and edited by U.R. Rao in "The Way to Communal Harmony". With a forward by Prof. Humayun Kabir, the Indian statesman and educator, and an introduction by Dr. Rajendra Prasad, former President of India, this work is published by Jivanji Dahyabhai Desai Navajivan Press, Ahmedadbad, India, price: 8 rupees.

EDUCATIONAL GROWING PAINS: A balance sheet of education on a worldwide scale drawn up by this year's International Conference on Public Education, convened at Geneva by UNESCO and the International Bureau of Education, showed that on the average countries are increasing their national educational budgets by 15% annually. Growth of school facilities, however, is meeting a serious obstacle in teacher shortages and 63 countries admitted having to hire insufficiently qualified teachers.

KARIBA FISHING FLEETS: The building of the Kariba Dam to contain the waters of the Zambezi River on the borders of Northern and Southern Rhodesia has created the world's largest artificial lake, covering 3,500 square miles. This vast inland sheet of water is destined to become the centre of a fishing industry. Its waters have been stocked with new fish, four ports are to be built as well as a fish processing factory, and eventually the annual fish harvest is expected to reach 14,000 tons.

THIRSTY INDUSTRIES: Out of every 100 gallons of water used in Western Europe only a few are used for drinking purposes. Factories in Belgium and Lorraine have reached a point where they use the same water five or six times over. Problems raised by this "industrial" water shortage will be studied during the International Hydrological Decade which UNESCO is now preparing. Data collected will help countries to make the best use of their hydraulic resources.

COPYRIGHT IN AFRICA: A meeting to discuss copyright problems in Africa was held recently in Brazzaville under UNESCO sponsorship. Its aim was to help African Member and Associate Member States of UNESCO to work out the main lines of protective legislation covering the works of writers, composers and artists in their territories.

NEW EYE ON THE SKY: To keep a star or planet under continuous observation, astronomers pass it from one observatory to another around the world like relay runners passing on a baton. One of the gaps in the astronomer's chain is in Siberia. To close this gap, the Astronomical Council of the Soviet Academy of Sciences is to build a major multi-purpose observatory in Novosibirsk with departments of astrometry, astrophysics, stellar astronomy, solar physics, radio-astronomy and planet astronomy.

AZTEC TOWN UNEARTHED: A team of French archælogists has discovered an Aztec town covering an area of nearly four square miles in the state of San-Luis Potosi, about 500 miles north of Mexico City. Thirty-four pyramids dedicated to Aztec divinities show that the town was an important religious centre.

News Flashes...

■ *The existence of an undersea "river" running eastwards along the Equator and flowing counter to the surface waters of the tropical Atlantic has been confirmed by an international fleet in a research programme organized by the Intergovernmental Oceanographic Commission, a body set up under Unesco's science programme.*

■ *More than one thousand million trees have been planted in Norway in the past 18 years. As an investment for future economic prosperity, Norway's Ministry of Agriculture aims to step up planting by at least 150 million trees annually during the next decade.*

■ *School enrolments in the United States rose from over 30 million to over 46 million during the period 1952-62, while college and university enrolment increased from 2,302,000 to 4,600,000. During the same period educational expenditure rose from $11,300,000,000 to $27,500,000,000.*

■ *The Russian Federation's Society for the Protection of Nature now has 6,700,000 members in 50,000 local organizations. Today 200,000 schoolchildren are members of the "Green Patrols" which help to protect trees and shrubs in towns and villages.*

RESCUING THE TEMPLES OF ABU SIMBEL

EFFORTS to rescue the Nubian Temples of Abu Simbel from being submerged under the waters of the Aswan Dam have now reached a decisive stage. The United Arab Republic has adopted a plan to cut up the temples and re-erect them on the hill above their present site and the United States Government has announced that it is ready to ask Congress to appropriate one-third of the cost of this major engineering feat. If the U.S. offer is finally confirmed the saving of Abu Simbel appears virtually assured.

The result of studies by a Swedish firm of consulting engineers, carried out at the request of the U.A.R., the new plan will cost $36 million. The U.S. contribution would be added to pledges by 43 Unesco Member States now amounting to $7,700,000, and the U.A.R., which will contribute $11,500,000 to the operation, has announced that it will sign contracts for the work as soon as the international aid total reaches $20,500,000.

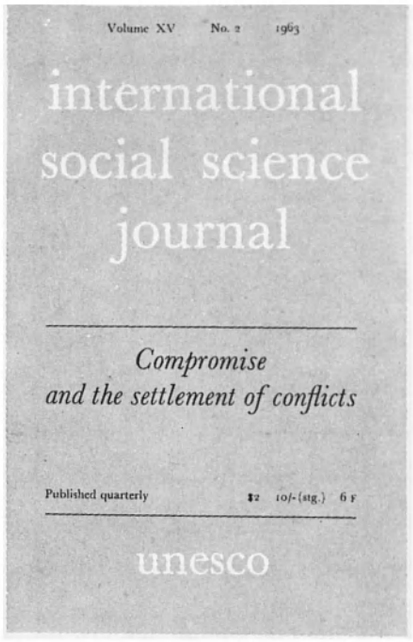
In dealing with 300,000 tons of fragile Nubian sandstone, engineers will use every technical means to avoid damage to the temples. No explosives can be used to remove the massive overburden of rock above the temples. Inside, a steel scaffolding will take new stresses and strains caused when the rock is removed. Facades, ceilings and walls will be cut into slabs whose shape will be determined by natural cracks and weaknesses in the stone. It is not expected that the gigantic jig-saw puzzle of fitting Abu Simbel together again on its new hillside site will be completed before 1969.

STAMPS SUPPORT CAMPAIGN FOR NUBIA'S MONUMENTS

Many Unesco Member States have issued or are proposing to issue stamps in support of the international campaign to save temples and monuments in Egypt and the Sudan which are threatened by the construction of the future Aswan Dam. Morocco has recently issued three stamps which show two of the colossi at Abu Simbel, a temple at Philae and a sculptured image of the goddess Isis (above) from the temple at Kalabsha. As agent in France of the U.N. Postal Administration, Unesco's Philatelic Service stocks all U.N. stamps and first-day covers currently on sale as well as many stamps issued by Unesco Member States to commemorate important events in the history of Unesco and the U.N. For prices and details write: The Unesco Philatelic Service, place de Fontenoy, Paris (7e).

Imp. GEORGES LANG, PARIS. IMPRIMÉ EN FRANCE.

UNESCO PERIODICALS



International Social Science Journal. The most comprehensive international journal of its kind because of its interdisciplinary approach: sociology, political science, law, demography, anthropology, etc. In each number it brings a series of original studies on a subject selected on account of its international impact or its bearing on current research, accompanied with news on research institutes, international meetings. (Quarterly).

Annual subscription : 32/6 ; $6.50.

Impact deals with the social aspects of science and technology, with subjects concerning relations between science and governments and problems of scientific organization. It is a quarterly for all thoughtful persons in all walks of life who are interested in scientific progress and the advancement of society.

Annual subscription : 9/6 ; $1.75.

Museum, a quarterly review of activities and research in the field of museography, is produced not only for those professionally interested in the running of museums, but also for teachers and students of art in general. Lavishly illustrated and printed entirely on art paper, it reports on outstanding achievements in display and conservation, presents new examples of museum construction and describes what museums are offering to the public in all parts of the world. Bilingual (English-French) texts are accompanied by summaries in Spanish and Russian.

Annual subscription : 32/6 (stg.) $6.50.

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HISTORY IN ROCK

Locked away in the rocky layers of the earth's crust are petrified vestiges of once-living things dating from different epochs of our planet's history. From such animal and vegetal fossils scientists have reconstructed major geological events and climatic changes that extend over millions of years, vistas and landscapes that disappeared eons ago. The delicately-veined leaf, slender branch and life-like fish shown here were found near Verona in northern Italy. They date back some 50 million years, long before the dawn of mankind. In that age the climate of much of the world was a tropical one and northern Italy was covered by a calm sea studded with coral atolls.

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